National Aeronautics and
Space Administration

NSTS 08271
REVISION A
JANUARY 20, 1994

Lyndon B. Johnson Space Center
Houston, Texas 77058

REPLACES
NSTS 08271
BASELINE ISSUE

SPACE SHUTTLE

FLIGHT AND GROUND SOFTWARE VERIFICATION AND VALIDATION REQUIREMENTS

REVISION LOG

REV LTR	CHANGE NO	DESCRIPTION	DATE
		BASELINE ISSUE (Reference S052486, dated 10/04/91)	11/21/91
A	2	REVISION A (Reference: S052486E, dated 11/26/93) also includes S052730A, CAR S041880B, SSP DOC–106, SSP DOC–163 and Change 1.	01/20/94

CHANGE SHEET

FOR

NSTS 08271 – Space Shuttle
Flight and Ground Software Verification
and Validation Requirements

CHANGE NO. 12

Program Requirements Control Board Directive No. S061461/(7–1), dated 6/19/00.(1)

July 21, 2000

Robert H. Heselmeyer
Secretary, Program Requirements
Control Board

CHANGE INSTRUCTIONS

1. Remove the following listed pages and replace with the same numbered attached pages:

Page	PRCBD No.
D-5	
D-6	S061461
D-17	
D-18	S061461
G-3	S061461
G-4 - G-5	
G-6 - G-7	S061461
G-8	

   NOTE: A black bar in the margin indicates the information that was changed.

2. Remove the List of Effective Pages, dated April 8, 1998 and replace with List of Effective Pages, dated July 21, 2000.

3. Sign and date this page in the space provided below to show that the changes have been incorporated and file immediately behind the List of Effective Pages.

_____ _____

Signature of person incorporating changes Date

NSTS 08271 – Space Shuttle
Flight and Ground Software Verification
and Validation Requirements

*Revision A (Reference PRCBD Nos. S052486, dated 11/26/93; S052730A, 10/20/93; CAR S041880B, dated 4/2/93; SSP DOC–106 and SSP DOC–163)

LIST OF EFFECTIVE PAGES

July 21, 2000

The current status of all pages in this document is as shown below:

Page No.	Change No.	PRCBD No.	Date
i – v	Rev. A	*	January 20, 1994
vi – vii	8	S060732	June 25, 1996
viii	Rev. A	*	January 20, 1994
1–1 – 1–2	Rev. A	*	January 20, 1994
2–1 – 2–2	Rev. A	*	January 20, 1994
3–1 – 3–2	Rev. A	*	January 20, 1994
A–1	8	S060732	June 25, 1996
A–2	Rev. A	*	January 20, 1994
B–1 – B–2	Rev. A	*	January 20, 1994
B–3 – B–5	8	S060732	June 25, 1996
B–6	8	S060732 SSP DOC-312	June 25, 1996, June 21, 1996
B–7 – B–8	8	S060732	June 25, 1996
B–9 – B–10	7	SSP DOC–307	May 9, 1996
B–11 – B–13	3	S060536	September 30, 1994
B–14 – B–15	8	S060732	June 25, 1996
B–16	3	S060536	September 30, 1994
B–17 – B–18	8	S060732	June 25, 1996
B–19 – B–23	11	S061065	March 23, 1998
B–24	10	S060875	February 11, 1997
B–25 – B–27	8	S060732	June 25, 1996
B–28	3	S060536	September 30, 1994
C–1 – C–12	Rev. A	*	January 20, 1994
D–1 – D–5	Rev. A	*	January 20, 1994
D–6	12	S061461	June 19, 2000
D–7 – D–17	Rev. A	*	January 20, 1994
D–18	12	S061461	June 19, 2000
D–19 – D–24	Rev. A	*	January 20, 1994

LIST OF EFFECTIVE PAGES

July 21, 2000

Page No.	Change No.	PRCBD No.	Date
E–1 – E–3	Rev. A	*	January 20, 1994
E–4 – E–5	5	SSP DOC–265	July 10, 1995
E–6	Rev. A	*	January 20, 1994
E–7 – E–8	5	SSP DOC–265	July 10, 1995
E–9 – E–11	Rev. A	*	January 20, 1994
E–12	7	SSP DOC–265	July 10, 1995
E–13	5	SSP DOC–265	July 10, 1995
E–14 – E–22	Rev. A	*	January 20, 1994
F–1 – F–2	Rev. A	*	January 20, 1994
G–1 – G–2	Rev. A	*	January 20, 1994
G–3	12	S061461	June 19, 2000
G–4	5	CAR S071024CB	January 29, 1996
G–5	Rev. A	*	January 20, 1994
G–6 - G-7	12	S061461	June 19, 2000
G–8	Rev. A	*	January 20, 1994

NSTS 08271

SPACE SHUTTLE

FLIGHT AND GROUND SOFTWARE
VERIFICATION AND VALIDATION REQUIREMENTS

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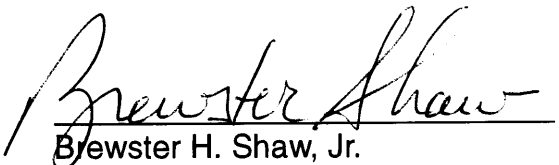
FOREWORD

Efficient management of the Space Shuttle Program (SSP) dictates that effective control of program activities be established. Requirements, directives, procedures, interface agreements, and system capabilities shall be documented, baselined, and subsequently controlled by SSP management.

Program requirements controlled by the Director, Space Shuttle Operations, are documented in, attached to, or referenced from Volume I through XVIII of NSTS 07700.

This document, which is to be used by members of the Flight and Ground Software community, defines the Space Shuttle Program baseline requirements for the Flight and Ground Software Verification and Validation process. All Flight and Ground Software Verification and Validation activity should be consistent with this plan and the unique items contained herein. The top level policies and requirements for Flight and Ground Software Verification and Validation are contained in NSTS 07700, Volume XVIII, Computer Systems and Software Requirements, Book 3, Software Management and Control.

All changes to NSTS 08271, Space Shuttle Program Flight and Ground Software Verification and Validation Requirements Document, in the form of SSP Change Requests shall be presented to the Systems Integration Review (SIR) for disposition. Change authority and management of the implementation strategy for the Verification and Validation requirements and processes in NSTS 08271 are hereby delegated to WA/Space Shuttle Systems Integration Office via the SIR. Revisions to this plan will be made as required to incorporate baseline changes to NSTS 07700, Volume XVIII, Book 3.



Brewster H. Shaw, Jr.
Director, Space Shuttle Operations

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APPENDICES

FIGURES

1.0 PURPOSE

The purpose of this document is to define and establish the Space Shuttle Program (SSP) requirements for the Verification and Validation (V&V) of SSP Flight and Ground Software used to control the Shuttle during launch and flight operations and to establish the activities and responsible organizations which constitute the V&V process. For the purposes of this document, SSP Flight and Ground Software includes Shuttle General Purpose Computers (GPCs) software, Space Shuttle Main Engine Controllers (SSMECs) software, Kennedy Space Center (KSC) ground software used for Shuttle checkout and launch processing, and Johnson Space Center (JSC)/Consolidated Control Center software used for Shuttle mission operations. This document baselines the V&V process roadmaps used for SSP Flight and Ground Software requirements definition, development, and mission preparation.

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2.0 APPLICABLE DOCUMENTS

The following documents of the date and issue shown form a part of this document to the extent specified herein. "(Current Issue)" is shown in place of a specific date and issue when the document is under Space Shuttle PRCB control. The current status of documents shown with "(Current Issue)" may be determined from NSTS 08102, Program Document Description and Status Report.

NSTS 07700 Volume XVIII, Book 3 (Current Issue)	Computer Systems and Software Requirements, Book 3, Software Management and Control Ref. Foreword
JSC 23474	Change Certification Policies for Mission Control Certain (MCC) Critical Software processors Ref. Apx. E, Para. 7.3.2
RF0004–004	SSME Reliability Data Reporting Requirements Ref. Apx. C, Para. 3.1

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3.0 INTRODUCTION

SSP Flight and Ground Software is partitioned into major elements by system location, function and managing organization. The major elements and managing organizations are: Space Shuttle GPC flight software, JSC Engineering Directorate; SSMEC software; Marshall Space Flight Center (MSFC) Astrionics Laboratory; KSC Ground Software, KSC Vehicle Engineering Directorate; and JSC/Consolidated Control Center (CCC), JSC Mission Operations Directorate. The V&V process for each of these elements is a self–contained appendix to this document. The accuracy and completeness of each appendix is the responsibility of the manager for that element.

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APPENDIX A (DELETED)

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APPENDIX B

SPACE SHUTTLE GPC FLIGHT SOFTWARE VERIFICATION AND VALIDATION REQUIREMENTS

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APPENDIX B

SPACE SHUTTLE GPC FLIGHT SOFTWARE VERIFICATION AND VALIDATION REQUIREMENTS

1.0 PURPOSE

The purpose of this appendix is to define and establish the Space Shuttle Program baseline requirements for the V&V processes and activities, and associated responsibilities, applicable to Shuttle GPC software, also referred to in this appendix as “Flight Software (FSW)”. This baseline comprises the V&V process roadmap used for FSW requirements definition, FSW development, and FSW mission preparation.

2.0 INTRODUCTION

SSP FSW is defined, developed and used by the FSW community. Prime members of the FSW technical community are: the NASA SSPO; Flight Crew Operations Directorate (FCOD); Mission Operations Directorate (MOD); Engineering Directorate (ED); Safety, Reliability, and Quality Assurance (SR&QA); and their supporting contractors (Rockwell International, Lockheed Martin, McDonnell Douglas, Lockheed, SOC, etc.). In general, the primary responsibilities of these organizations in the FSW development, test and use are as follows: the NASA SSPO approves all FSW requirements changes, post–development performance tests specifications (Level 7 & 8), and SAIL test requirements; the Avionics Systems Division (ASD) of the ED is responsible for technical management of the OI FSW development, verification, and maintenance, the flight crews of the FCOD are the ultimate end users of FSW during a STS mission; MOD develops the mission FSW requirements for each STS mission and is responsible for technical management of FSW reconfiguration, Level 8 verification testing, reconfigured FSW maintenance, crew training, and Shuttle mission simulation operation; SR&QA monitors FSW requirements, documentation, and tests to ensure that they are in accord with approved NASA standards and procedures; and the NASA supporting contractors perform the actual translation of FSW requirements into FSW computer programs and integrated mass memory loads for use in the Space Shuttle GPCs and verify and validate the operational FSW for each STS flight.

Two contractors, Lockheed Martin and Rockwell International, respectively, are responsible for the development and verification of the Primary Avionics Software System (PASS) and Backup Flight System (BFS) basic software.

These two contractors are also responsible for the mission specific reconfiguration of the FSW and the flight IMMU load build. Additionally, they are responsible for the verification and validation of the reconfigured product per the program approved Performance Test Plan (PTP).

4.0 SPACE SHUTTLE FLIGHT SOFTWARE (FSW) COMMUNITY

Each member of the FSW technical community identified above has different objectives, goals, or perspectives with respect to the actual development and operational utilization of Shuttle FSW. Members of the FSW community support FSW development, test, and operations in multiple facilities. The various viewpoints and operational use, by members of the FSW community, provide an effective V&V function throughout the FSW life cycle. Examples of the role of different viewpoints in the V&V process are provided in the remainder of this appendix.

4.1 SPACE SHUTTLE PROGRAM OFFICE

The Space Shuttle Systems Integration Office (SIO) is responsible for controlling FSW requirements. The SIO evaluates proposed FSW changes with respect to SSP priorities and resources available for FSW requirements definition, FSW code development, and verification. A process has been implemented to assist in the prioritization and orderly development of potential FSW changes. Two essential elements of the process are the “FSW Change Proposal (FCP)” and the “Three Year Plan”. The FCP is a compact definition of a proposed FSW change which is presented with justification based on anticipated SSP benefits. Approval of an FCP initiates the preparation of a FSW CR containing fully detailed requirements changes and configured for a specified OI. The “Three–Year Plan” is an OI content planning baseline, with minimum yearly updates, approved by the Program Requirements Control Board (PRCB). It defines the major change content intended for the next three OIs. The change content may be identified in terms of existing CRs, FCPs, or by narrative description. The implementation of the Plan is administered by the SASCB. For each OI, the Three Year Plan content is a given. If not already available, CRs are developed to meet the plan. The approximate PASS and BFS implementation impacts of these CRs are estimated. Other CRs and/or FCPs are reviewed to compile a prioritized Candidate List. If development resources remain after the Three–Year Plan CRs are accounted for, CRs from the Candidate List are selected (or prepared in response to approved FCPs) to approximate the projected available resources. Following that, each CR is reviewed in detail by the developer to determine readiness for baselining, impact to GPC memory, and impact to resources (manpower). The result of these reviews is a list of CRs which are mature and implementable in conjunction with the Three–Year Plan CRs. This “Ceiling List” is presented to the PRCB for approval. The individual CRs are approved by the SASCB.

4.2 MISSION OPERATIONS DIRECTORATE

MOD develops the operational requirements for all components of a Shuttle mission. Included are the plans and procedures for all communications, mechanical systems, remote manipulator system, electrical and environmental systems, flight design, flight

dynamics, navigation (ascent/entry/orbital), ground support, reconfiguration, and mission training. MOD is composed of independent divisions of two or more branches supported by multiple contractors. The flight planning process involves a top down – bottom up structured approach to mission planning. Top level objectives are broken down into individual objectives for MOD divisions and/or branches who develop plans within their area of responsibility to attain their assigned mission objectives. Each lower level plan is integrated into the final mission plan and subjected to objective testing and management review prior to approval. MOD uses the SMS complex located in JSC Building 5 for validation of mission plans and procedures. When the FSW mass memory loads are released for mission operations, MOD uses the SMS with this load to train the flight and ground crews. The SMS is not used as a formal GPC FSW V&V tool. However, DRs written against the SMS GPC software are reviewed for applicability to the mission GPC FSW load.

V&V Role: Once the mission plan has been approved, MOD organizations and/or their support contractors review and update mission requirement documents as required to accomplish the mission objectives stated in the areas of communications, mechanical systems, remote manipulator system, electrical and environmental systems, flight design, flight dynamics, navigation (ascent/entry/orbital), ground support, reconfiguration, and mission training. Changes are validated in MOD flight simulations using the SMS and flight planning software tools. The evaluation and approval process within MOD performs an effective V&V role for developing and verifying the FSW requirements.

4.3 ENGINEERING DIRECTORATE

The responsibility of the ED is to ensure that the Shuttle Vehicle and its supporting equipment can functionally perform the mission objectives without exceeding safety limits and to ensure that the Shuttle FSW is developed and verified to meet all approved requirements. The ED supports the design and development of SSP hardware and software systems. Included are: regenerative life support systems; guidance, navigation, and control hardware and software systems; data systems hardware and software; electrical power, and propulsion systems; and remote manipulator systems. ED is composed of independent divisions with two or more branches supported by systems engineering contractors. Each Shuttle hardware or software system is subjected to detailed analysis by ED personnel to ensure design limitations of Shuttle hardware and software systems are not exceeded. ED personnel use the Software Development Facility (SDF) to perform all Level 6 and 7 verification tests. ED personnel with Rockwell–Downey contractor support utilizes the SAIL to analyze Shuttle avionics hardware and software interfaces and operations. If ED determines that new hardware or software systems are required, appropriate systems requirements specifications are prepared and then submitted to the SSPO for approval. After the requirements have

been approved, FSW implementation, if required, is then performed by the ED/ASD organization with contractor support from Lockheed Martin for the Primary FSW and Rockwell–Downey for the Backup FSW.

V&V Role: The ED has systems engineering responsibility for the total Shuttle hardware and software systems and evaluates the capability of each system to accomplish planned mission objectives. The ED/ASD reviews each change in the FSW (including post OI delivery patches) by means of Level 6 and 7 SDF testing to provide an independent NASA assessment and signoff on the completeness and correctness of all FSW changes. The mission plan is evaluated by ED personnel for each phase of flight operations and FSW logic or constraints to ensure that mission objectives can be achieved. When the FSW mass memory loads are released for mission operations, ED uses the SAIL with this load to verify hardware and software compatibility. The independent evaluation of mission performance by ED ensures that the modified software is compatible with the requirements as approved by the SSPO.

4.4 SAFETY, RELIABILITY, & QUALITY ASSURANCE (SR&QA)

SR&QA is concerned with Shuttle Vehicle, ground support systems and personnel safety, reliability of SSP hardware and software systems, maintainability of SSP equipment and documentation, and SSP quality assurance of hardware, software, and documentation. With a focus on safety quality issues, SR&QA is a voting member to the SASCB. To ensure appropriate dispositioning of discrepancies against the flight software and of changes proposed to the flight software, SR&QA analyzes Operations (OPS) notes/waivers, user notes, hazard reports, FMEA/CILs, crew procedures, flight rules, LCCs and the OMRSDs to ensure that any impacts are addressed and acceptable from a safety standpoint. SR&QA assesses the readiness for Flight of the Space Shuttle onboard flight software on a mission–to–mission basis by assuring that all requirements are identified correctly, all processes associated with building the mass memory are performed, and all issues are closed prior to flight.

V&V Role: The independent evaluation of flight software discrepancies/changes by SR&QA ensures that the flight software meets requirements for safety, quality, and mission assurance.

4.5 FLIGHT CREW OPERATIONS DIRECTORATE

FCOD is concerned with the satisfactory operation of the total integrated Shuttle System, including both hardware and software in the full range of nominal and off–nominal mission tasks. FCOD initiates changes and evaluates proposed changes and identified discrepancies for acceptability in the following functional areas: flight safety, crew interface suitability, closed–loop performance, and operational effectiveness. The SMS, SAIL, and Shuttle Engineering Simulation (SES) are the primary tools for flight crew evaluations.

V&V ROLE: The flight crew assesses each change or discrepancy for flight safety and operational impacts. Depending on the situation, desktop review, SMS or SES simulation, or some combination of the three is used in the evaluation. The SAIL is used to validate flight software performance in a variety of nominal and stressed scenarios.

4.6 FLIGHT SOFTWARE DEVELOPMENT CONTRACTORS (LOCKHEED MARTIN, ROCKWELL INTERNATIONAL)

The development contractors are contracted to the ED ASD (PASS) and the Space Shuttle Vehicle Engineering Office (BFS). Development contractors are primarily concerned with the implementation of FSW modules and their operation in Shuttle computers. Each contractor uses functionally independent organizations to analyze change requirements, design and code FSW changes, manage FSW configuration, build FSW OI loads, and verify that changes are correctly implemented. The development contractors perform rigorous reviews throughout the software definition, implementation, and verification cycles. These review processes cover requirements, design, code, test procedures, and test results and are designed to eliminate errors early in the software life cycle.

V&V Role: The development contractors maintain functionally independent organizations that review and examine the FSW at each stage of development. The requirements group ensures that the specified requirements are understood and that the FSW module designs incorporate the intent of these requirements. The programming group ensures that the FSW module designs are coded properly according to approved development standards. The test group verifies that the code executes properly and accomplishes the functions stated in the requirements. The build group ensures that only approved FSW modules are used in loads released for verification and final delivery.

4.7 OPERATIONS CONTRACTORS (SPACE OPERATIONS CONTRACT [SOC], LOCKHEED MARTIN, ROCKWELL, ETC).

Operations contractors are defined as those contractors who reconfigure the FSW OI loads delivered by the development contractors for use on specific missions. Lockheed Martin and Rockwell International/Downey are responsible for preparing all reconfigured mission loads from the OI base delivered from the development contractor. The contractors integrate development loads with GFE FSW data, initialization data, telemetry format data, and FSW patches (late CR/DR correction) to prepare an integrated mass memory load for the Shuttle flight computers. They then perform a mission specific series of tests (Level 8) to verify the final integrated mass memory system performance.

The prepared mission–specific releases are used by various operations contractors in JSC simulation facilities (SMS and SAIL) to train and prepare for each specific mission and/or validate the ability of the integrated mass memory loads to perform the specified mission. For example, SOC personnel are concerned with the telemetry and command compatibility with the Mission Control Center (MCC) software. SOC and flight crew personnel are concerned with operational flight training for the planned mission; and Lockheed examines the avionics hardware compatibility with the integrated mass memory load, as well as its interface with the launch processing system software.

V&V Role: Lockheed Martin and Rockwell International personnel perform validation testing on the integrated mass memory loads. Other operations contractors evaluate FSW performance in detail for each of their areas of concern. This provides many views of the FSW by different contractors which result in an effective V&V look at the delivered FSW product. Problems found during operations by any user are documented via DRs and tracked by the SSP, FSW development contractor technical manager (ED/ASD), FSW reconfiguration contractor technical manager (MOD/Reconfiguration Management Division (RMD), and the SR&QA until corrected or satisfactorily resolved.

4.8 SYSTEMS DESIGN CONTRACTORS (ROCKWELL, LOCKHEED, CHARLES STARK DRAPER LABS, MC DONNELL DOUGLAS)

Systems design contractors are defined as those contractors who verify: (a) the FSW loads are compatible with hardware interfaces; (b) the FSW performs as designed; and (c) the FSW is compatible with mission requirements. These contractors include Rockwell International and ED subcontractors: Lockheed, Charles Stark Draper Labs, and McDonnell Douglas.

The system design contractors form the avionics verification test teams which are responsible for integrated verification of the FSW and avionics system hardware. The SAIL is used as the primary integrated avionics verification tool. However, SPF testing and audits are also used to verify FSW performance.

The verification teams establish test requirements in team meetings and submit them to the Shuttle Avionics Systems Review (SASR) board for approval. Once approved, any SAIL tests required are scheduled and conducted. This process is followed for both the engineering and flight cycles of the FSW.

In preparation for SAIL testing, detailed test design reviews are performed to ensure all verification objectives will be met and that the SAIL facility can support any required failure scenarios. Detailed Test Case Procedures (TCPs) are generated from the test requirements by SOC personnel and reviewed by the system design contractors.

The results of each verification test are compared to pass/fail criteria consisting of program requirements (FSSRs, PRDs, CPDS, etc.) and, when appropriate, signature data generated by independently coded simulations. If the test results do not meet pass/fail criteria, including signature data, anomaly reports are written which may result in FSW DRs being generated. Any DRs resulting from verification testing are then subsequently dispositioned through the SASCB and may result in future code changes via software SCRs.

Both the PASS and BFS systems are verified by this process. Though not identical, both systems are derived from similar software requirements. Thus, in regions where the same software requirements apply, similar results should be obtained when both systems are subjected to the same conditions. Where appropriate, flight critical mission phases (ascent and descent) are tested for PASS and BFS utilizing identical conditions and run scenarios. The results from these tests are compared at key mission points to determine if both systems agree. If the results do not agree favorably, anomalies are written to document the test results. FSW DRs are written if the differences between the systems are determined to be due to PASS or BFS errors.

V&V Role: The system design contractors independently perform verification of the PASS and BFS FSW loads. Verification requirements are independently generated, compared, integrated, and jointly presented for approval at the SASR. SAIL tests are used to verify software and integrated hardware/software performance. Test results are compared to pass/fail criteria which includes program requirements and independently generated off–line simulation signature data. In addition to the explicit testing mentioned above, the BFS is a validation of the PASS. Since the software for the PASS and the BFS are developed and coded by different organizations, comparing critical outputs provides validation of both software systems.

4.9 JSC SPACE SHUTTLE VEHICLE ENGINEERING, KSC, AND MSFC PROJECTS

JSC Space Shuttle Vehicle Engineering is responsible for assessing the impact of FSW changes, DRs, and issues with Orbiter systems with the intent to ensure compatibility between the FSW and the Orbiter systems. This includes sponsoring FSW changes; conducting SAIL tests every OI and/or as required; and evaluating FSW process/policy changes, etc.

Two KSC organizations, the Engineering Directorate and the Payload Directorate, assess FSW changes. KSC Engineering is responsible for assessing the impact of FSW changes, DRs, and issues with KSC ground systems with the intent to ensure compatibility between the FSW and the KSC ground systems/software. This includes sponsoring FSW changes as required; taking action to update ground software, procedures, and test plans; conducting SAIL/KATS LPS tests every OI as required; and evaluating FSW process/policy changes, etc. KSC Payloads is responsible for all of the

above as it relates to Shuttle/Payload KSC interfaces. Specifically, this includes establishing FSW requirements for KSC Payload testing, conducting KSC Payload testing, and documenting any discrepancies as a result of KSC/Payload interface checkout.

The MSFC FSW community representatives (SSME, SRB, and ET Projects are represented as required) are responsible for assessing the impacts of FSW changes, DRs, and issues with the respective MSFC Project element with the intent to ensure compatibility between the FSW and their respective Project's system. This includes sponsoring FSW changes as required; taking action to update their element system; supporting SAIL tests of the FSW/Project element interface as required; evaluating FSW process/policy changes; etc.

V&V Role: The JSC Space Shuttle Vehicle Engineering, KSC Engineering, KSC Payloads, and MSFC Projects representatives provide independent evaluation and subsequent testing of FSW changes, DRs, and issues affecting their respective interfaces.

5.0 DEVELOPMENT APPROACH

There are three distinct "roadmaps" for the current SSP FSW development process – Definition, Development, and Mission Preparation. The FSW Definition Roadmap identifies the activities and SSP approval processes (SASCB/PRCB) used to define the FSW requirements and ensure program resources are allocated to facilitate implementation schedules. The FSW Development Roadmap identifies the activities and ASD/development contractor controls used to implement approved SSP requirements and verifies that the delivered FSW correctly implements these requirements. The FSW Mission Preparation Roadmap identifies the activities and programmatic controls used to transform the delivered FSW into a Flight Computer Mass Memory Unit (MMU) Load and to validate that the MMU is capable of properly and safely supporting the Shuttle design mission.

The SSP FSW process is an ongoing, iterative, and dynamic process. Provisions have been made to accommodate FSW changes throughout this FSW process.

5.1 FLIGHT SOFTWARE DEFINITION ROADMAP

The FSW Definition phase begins with a SSP requirement defined by the technical community and ends with an approved FSW Implementation Plan. The implementation plan includes approved requirements, resource allocations, and development schedules. The SSP FSW provides evolving capability to accomplish a wide range of Shuttle missions. FSW requirements changes are defined in Software Change Requests (SCRs). Problems found during operations of a FSW load are documented in DRs that may require changes to the operational code or FSW requirements to correct. Each major capability change set is identified as an OI. Shuttle missions use a specified OI

modified by mission or vehicle specific requirements. Mission and vehicle specific requirements are uniquely described in Data Change Requests (DCRs) approved in the SASCB weekly meetings. The FSW Definition Process is allocated approximately three months on the FSW development template, and ends with an approved baseline CR identifying the FSW CR/DRs to be implemented in an OI (see Figure B–1).

5.1.1 Flight Software Needs

New OIs, FSW modifications, mission data, new designs and FSW corrections begin with an expressed need defined by the SSP FSW community. These needs are identified through flight or mission plans, vehicle or equipment modifications, flight or ground crew requests, program directives or objectives, etc.

5.1.2 Needs Analysis

Once a need is defined, the FSW community must perform analysis to determine if these needs should become approved requirements for the SSP FSW. These analyses are performed by knowledgeable Shuttle avionics engineering personnel through Multi–Organizational Design Engineering (MODE) Teams by mission planning personnel, vehicle or flight equipment designers, FSW development personnel, payload users, or flight and ground crew personnel.

The end result of this analysis will define the actual FSW requirements for further consideration either into an OI or adding to a specific STS flight or mission.

The SIO is responsible for leading and coordinating the software requirements development activity by developing program priorities and authorizing the necessary mode teams to develop multidiscipline CRs. The assigned technical mode team leads are responsible for developing a complete functional CR that is technically and operationally compatible and consistent with the existing program design and safety requirements. Specifically, civil servant Principal Function Managers (PFMs) and their RI counterparts are responsible for developing consistent requirements for their area of responsibility. The other assigned mode team organizations are responsible for evaluating the proposed CR with respect to functional impact on their respective discipline.

Embedded V&V Activity: V&V activity is accomplished through the system engineering analyses performed by FSW community members. The FSW needs formulated by the community at large are subjected to systems engineering analysis by other members of the FSW community to validate requirements. Once the knowledgeable FSW community personnel determine a valid FSW requirement exists, a sponsor prepares the necessary change documentation.

5.1.3 Discrepancy Report Analysis

DRs are problems or anomalies discovered in the operational FSW or potential hazards identified in the requirements design. DRs are generated throughout the software life

cycle by the various members of the FSW community involved in development, verification, testing and/or operations (e.g., FSW developers, flight crew, mission controllers, Level 8 testing, certification testing, SAIL integrated hardware/software testing, etc.).

DRs are analyzed to determine the appropriate disposition (i.e., waive, fix, Program notes, no DR). This analysis includes a determination of a need for a FSW requirement change. If analysis indicates that a requirements change is needed, the DR disposition will recommend that a CR or DCR be submitted by the FSW community for consideration. Otherwise, if a code fix is required, the appropriate FSW development group will provide the necessary implementation plan for correction.

ASD is responsible for managing and maintaining the FSW development DR process. MOD is responsible for managing and maintaining the FSW reconfiguration DR process. All other affected elements of the FSW community are responsible for the evaluation of the DRs, helping to develop the system impacts and disposition rationale. The SASCB is responsible for approving the program disposition of FSW DRs.

Embedded V&V Activity: Discrepancy reporting is a V&V activity performed by the continuous utilization, evaluation, and review of the operational FSW by the technical community. The FSW evaluation DRs found are subjected to detailed systems engineering analysis to determine their criticality and validity. The FSW community software engineers evaluate the range of options available to correct the discrepancy and prepare the necessary disposition recommendations for action by the SASCB.

5.1.4 Space Shuttle Program Control

The sponsor for a FSW change will prepare the necessary CR/DCR and present it to the SASCB. If additional resources or SSPO approval are required, the sponsor must also defend the proposed change to the PRCB.

5.1.5 Requirements Analysis

The FSW development contractors evaluate the requirements and determine an approach to implement them. Once this approach is determined, the development contractor must evaluate the resources required for implementation and develop an implementation schedule. This schedule becomes a recommendation to ASD from the development contractor. ASD reviews the recommended implementation plan and approves their presentation to the SASCB. If there are issues with the development contractor's understanding of the requirements or their intent, these issues are resolved with the sponsor and reviewed by the community in a formal requirements inspection. A correction CR is submitted if required.

ASD is the responsible lead organization for ensuring an appropriate implementation plan with the FSW development contractors, including resources and schedule. The

FSW community organizations are responsible for maintaining checklists and CR evaluation documentation for their respective processes, including desk audits/assessments and required engineering simulation requirements. The organization/PFM that is accountable for the most significant change in the proposed CR is responsible for performing the necessary engineering simulations with the proposed FSW change and reviewing the CR content and simulation results with the respective technical panel, e.g., GN&C panel, abort panel, etc. Also, the SASCB representatives are responsible for developing an integrated position on CRs with their PFMs, I–Load owners, subsystem managers, etc.

Embedded V&V Activity: V&V activity is accomplished through the development contractor's system requirements analyses organization. Communications with other FSW community members adds required insight to evaluate and identify requirements issues. Corrective actions are recommended as necessary.

5.1.6 Requirement Inspections

The FSW contractor evaluates every CR and CR modification. For many CRs, a requirement inspection will also be conducted. Requirement inspections are formal requirement reviews with a moderator, ASD analysts, FSW contractor requirement analysts, FSW community peers, software programmers, and verification representatives. These reviews are open to all members of the technical community and will often include the author of the requirements documents. The purpose is to ensure that the intent of the requirements is understood by the FSW contractor and to clarify the interaction of multiple FSW principal functions affected by the new or modified requirements. The requirement inspection should identify issues with the requirements or risks associated with the implementation of each CR inspected and resolve any requirements issues identified.

The FSW contractor evaluates each CR and CR modification for the need to inspect that CR or CR modification. Requirement inspection may be waived for a CR or CR modification when, in the judgment of the FSW contractor, a requirement inspection would provide no additional value to the evaluation of the requirements. A requirement inspection will be conducted even if the FSW contractor determination has been to waive it, if requested to do so by the SASCB.

The ASD is responsible for coordinating the requirements inspection process with the FSW development contractors and the necessary FSW technical community. The FSW technical organizations/PFMs are responsible for ensuring that the intent of their requirements is communicated to the FSW developers.

Embedded V&V Activity: The V&V activity is through the involvement of all organizations in the FSW community. They effectively validate the interface compatibility and

appropriate interactions between all the affected functions. As a team, they verify that the requirements are correct and complete assuring that the intent is uniformly understood throughout the FSW community.

5.1.7 Space Shuttle Program Authorization

The NASA FSW management and their development contractor present an implementation plan for either a new OI or a mission specific CR/DR for a current OI to the SASCB. If additional budgeted FSW resources are required, the proposed change must be presented to the PRCB for approval.

The output of the SASCB is an approved OI baseline content and schedule identifying the CR/DRs to be implemented for a specific FSW operational capability. The SASCB takes the recommended OI baseline content and schedule forward to the PRCB for formal program approval. The SASCB meets weekly, and approves mission specific CR/DCR/DRs for implementation or acceptance for flight with waivers or user notes up to flight time.

5.2 FLIGHT SOFTWARE DEVELOPMENT ROADMAP

The FSW Development Phase begins with the approved baseline identifying the CR/DRs approved for implementation in a new OI and ends approximately 20 months later with the delivery of new PASS and Backup Flight Software (BFS) software OI loads to the FSW Mission Preparation Phase. This OI software is released to the NASA users by ASD at the formal OI Configuration Inspection (CI) milestone (see Figure B–2).

The FSW development is the responsibility of the Primary Avionics Software System contractor – Lockheed Martin, and the backup flight software contractor – Rockwell International under the technical management of ASD. Both contractors utilize the NASA JSC SDF to develop and test FSW until a new OI is delivered to NASA at CI. The SDF activities are referred to as “Backroom” activities. The PASS and BFS FSW is designed, coded, tested, and verified in this phase. The FSW is subjected to two levels of independent verification – Level 6 (Functional) testing and Level 7 (Performance) testing.

5.2.1 Design, Code, Unit/Module Test

The development contractors use separate groups to develop FSW in the SDF. Separate groups are responsible for all requirements analysis and programming: one for managing configuration and building FSW releases; and another group is responsible for verification testing of the FSW for the new OI delivery. Members of these groups attend inspections as presenter or peers, as required by the type or complexity of the changes, to review the developed products. Each inspection follows an inspection checklist to ensure that all procedures, and standards have been followed. Approval is received from the moderator reflecting the direction of the inspection team.

DESIGN: Approved CRs contain the requirement specifications that the new OI delivery is expected to provide. These requirements are the basis for FSW designs. Lockheed Martin and Rockwell convert the requirements stated in approved CR/DRs to detailed software designs which are documented in Detailed Design Specification (DDS) documents. Design inspections are then held where the designers present their designs to knowledgeable PASS or BFS FSW engineers for review.

CODE: Upon completion of the detailed design, the PASS or BFS software developer then writes FSW code implementing the design. A listing of the code is prepared and presented to knowledgeable PASS or BFS programmers for review at a Code Inspection. The design inspections and code inspections are sometimes combined for less complex implementations.

UNIT/MODULE: Once the code is completed, Unit (PASS Level 1, BFS Level 2) tests are performed to verify equations, logic paths, and/or range of values. Module (PASS Level 2, BFS Level 3) tests are executed, if required, to verify the module interface (Input/Output) performance. These tests are sometimes combined for less complex changes. The results of these Unit Tests are presented to knowledgeable PASS or BFS programmers for review at a Test Inspection.

Embedded V&V Activity: Each activity has detailed written procedures which the developer's software quality assurance personnel monitor for compliance. Preparation for each inspection includes a review of the procedures and standards utilized to accomplish a design, code a module, or perform a test. Detailed checklists are completed and then reviewed by the attendees prior to inspections required for code design and test reviews.

V&V is the responsibility of the development contractors. They have accomplished this by forming independent organizations responsible for tracking and verifying the approved requirement changes to the FSW. All reviews and inspections are controlled by peer moderators, without management involvement other than oversight review and approval of FSW development standards and procedures.

The design is inspected to ensure that the design reflects both the stated requirements as well as the intended requirement. The code is inspected to ensure conformity to FSW standards, prevent unintended functions, and control inefficient Central Processing Unit (CPU)/memory consumption. Design and code inspections are sometimes combined for less complex changes. Tests are inspected to ensure that tests are performed at applicable levels of FSW development (i.e., Unit, and Module) prior to beginning FSW integration via the load build process.

5.2.2 Load Build and System Test

The OI development cycle has approximately a 16–month template. During this period, multiple load releases will be built. Each FSW load release contains the preceding load

release plus updates that have completed the development process (design, code, unit/module test). As each load is being developed, it will receive functional level testing in the SDF. After each load is built, it will receive system integration testing before release for verification testing. The object of these tests is to test functional interfaces, multiple functions, timing, system interface, and mission profile. Each new load is released to the Level 6 test group for detailed verification tests upon successful completion of the system level tests. Level 7 test group begins performance verification tests when all of the approved CR/DRs have been included in a load release at the First Article Configuration Inspection (FACI). The final development OI load release is known as the CI load.

Embedded V&V Activities: The PASS or BFS development contractor maintains responsibility for all V&V activities until the CI load is released.

The development contractor FSW configuration management ensures that FSW modules are never added or changed unless proper authorization and procedures have been followed. The system integration tests conducted on each new load build consist of standardized system tests of the basic load characteristics and capabilities. Tests are performed using SDF ground unit (non–flight) GPCs with a functionally complete FSW MMU load.

5.2.3 First Article Configuration Inspection

This is a formal review milestone in the OI development template. This milestone officially begins the verification phase of an OI. At this point all CR/DRs have been incorporated into the FACI Verification Load, which normally becomes the base load for the next OI entering development. This milestone occurs approximately eight months after the initial OI baseline has been approved by the SASCB. The development contractor reports on OI development progress, Level 6/7 verification testing planned, and any planned post–FACI work.

The ASD is the lead organization conducting the FACI review with the FSW development contractor. The impacted PFMs are required to review the FSW development contractor's design as documented in the detail design specifications and review the test planning for completeness relative to their FSW change coverage. All FSW community organizations are encouraged to participate.

Embedded V&V Activity: This is the first review in the OI development cycle where all elements of the FSW community participate. This review allows appropriate members of the FSW community to evaluate the OI status and determine if required development for all functions has been achieved.

5.2.4 Verification Test Procedure Reviews

Two levels of testing are performed on operational hardware by independent development contractor organizations. Detailed functional (Level 6) testing consists of module functional tests against requirements. System level (Level 7) performance testing is conducted under operational flight conditions.

Inputs to this activity are the CR/DR baseline documents approved by the SASCB. Level 6 test analysts develop Verification Test Procedures (VTPs) to be used during testing. Level 6 VTPs are standard functional tests for FSW Principle Functions documented in SDF data sets. Specific tests are selected or modified from these standards. New tests are prepared, as appropriate, by Level 6 test analysts to test new or modified functional capabilities. Generic Level 7 tests consist of Guidance, Navigation, and Control (GN&C) System Integrity Tests, System Services Tests, and Vehicle Cargo Systems Tests. Level 7 OI specific tests are New Capability Performance Tests designed to verify the new performance capability provided by one or more CRs implemented in the new OI. Level 7 Verification Tests are developed through a community review process and are documented in a Verification Test Specification CR approved by the SASCB.

Embedded V&V Activities: During the Level 6 Verification Test Procedure Inspections conducted by the development contractors, ASD and the FSW technical community provide inputs, identify issues and review test procedures. The Level 6 test procedures are approved by ASD when all community issues are closed. The Level 7 test specifications are reviewed in Test Coordination Team (TCT) meetings attended by interested parties from the FSW community. The resulting Level 7 Verification Test Specification is documented in a CR and formally approved by the SASCB. The object is to ensure that planned tests verify requirements as well as overall system performance.

5.2.5 Functional Verification Testing

This activity is the execution of the Level 6 Functional Tests approved in the preceding activity. Level 6 testing is very flexible in that each test focuses on FSW module changes. The FSW is functionally tested by exercising, on flight equivalent operational computer hardware in the SDF, FSW Principle Functions affected during CR/DR implementation. Tests can include partial trajectories and engagement transitioning (BFS only) if a function was affected by changes. Tests may include overriding math model inputs with out–of–limit stress conditions.

Functional Test Reviews: Level 6 functional tests are reviewed independently by ASD and the FSW community. Tests are conducted on all software changes throughout the development template. Each Level 6 test case has a review scheduled by the development contractor to review the test results. These reviews are attended by development contractor personnel, NASA ASD analysts, and other FSW community personnel as required. The test results are reviewed, and issues are recorded for resolution. The

Level 6 test results are accepted by ASD as a certification that the delivered software conforms to NASA approved requirements. Level 6 issues not closed by ASD are reported by the developer at the CI. Level 6 Epilogues (Test Reports) are published approximately six weeks after the CI and delivered to members of the FSW community upon request.

The ASD is responsible for ensuring these test reviews are conducted satisfactorily and that the tests confirm that the software is ready for NASA acceptance. The impacted PFMs and FSW system verification personnel (civil servant and contractor) are responsible for reviewing these tests for completeness.

Embedded V&V Activities: Development contractors are responsible for performing the tests according to the procedures and conditions approved in the verification test procedure. Functional tests are designed to examine the total functional range of specific principle functions provided by the CR/DRs implemented in the new OI. Participation of affected parties from the FSW community in the VTP Inspections and use of independent organizations by the development contractor for Level 6 testing accomplish the V&V task during the design, conduct, and review of tests. Detailed results from each Level 6 test case are evaluated and approved by ASD with the support of the technical community members.

5.2.6 Performance Verification Testing

This activity performs the Level 7 Performance tests contained in the Verification Test Specification CR approved by the SASCB. Level 7 testing normally begins with the delivery of the FACI Verification Load, and may also utilize later verification load deliveries to complete Level 7 testing. The tests are performed in the SDF using operational flight equivalent computer hardware, and simulated mission conditions emulating an OIs operational mission environment.

Level 7 tests place emphasis on evaluating PASS or BFS system performance instead of Principle FSW Functions. The Level 7 tests more closely resemble the flight profile than the Level 6 tests. The tests do include engage transition testing (BFS only).

Performance Test Reviews (PTR): Each New Capability and Generic Test report is mailed to members of the FSW community on the Level 7 Test Report Distribution List four to six weeks prior to the PTR for review and evaluation. The PTR meetings are completed 1.5 to 3 weeks prior to the CI and any unresolved Level 7 issues are reported by the developer at the CI. The developer will resolve all Level 7 issues remaining open at the CI, and prepare a supplemental report for the CI attendees.

The ASD is responsible for conducting these test data analysis reviews. The impacted PFMs and FSW hardware/software system verification personnel (civil servant and contractor) are responsible for reviewing these test results for adequacy as verification completion commitments.

Embedded V&V Activities: By use of standardized generic Level 7 tests, each OI delivery is tested to the same specifications under the same conditions. New Capability Performance tests are designed to exercise the full envelope of capabilities provided by the specific CR/DRs implemented in the new OI. Participation of the FSW community in the TCTs and PTRs in addition to use of independent organizations by the development contractor for Level 7 testing accomplish the V&V tasks during the design and conduct of tests.

EXCEPTION: The OI–27 New Capability and Generic Test reports will be mailed to members of the FSW community two weeks prior to the PTR. The PTR meetings will be completed within six weeks after CI and any unresolved issues will be documented via a new FSW CR or DR.

5.2.7 Configuration Inspection

This is a formal review milestone in the OI development template at which the development contractors report on OI development issues and Level 6/7 verification test issues, deliver updated FSW documentation, and release the CI loads to NASA. This milestone officially completes the development phase of an OI. At this point, all CRs/DRs have been incorporated into the CI loads. This milestone occurs approximately eight months after FACI.

The ASD is responsible for officially accepting the new OI from the FSW development contractor. The FSW technical organizations are responsible for supporting ASD, ensuring that their requirements have been adequately met.

Embedded V&V Activity: The CI is preceded by Level 6 test results meetings and Level 7 Performance Test Review (PTR) meetings. Each review performs a V&V function by including members of the technical community in the review and verification of test results. The purpose of a review is to ensure that the requirements contained in the CR/DRs approved by the SASCB for implementation in an OI have been implemented correctly and verified according to approved SSP standards for FSW development.

EXCEPTION: The OI–27 Level 6 test results meetings and Level 7 PTR meetings will be completed within six weeks after CI.

5.3 FLIGHT SOFTWARE MISSION PREPARATION ROADMAP

The FSW Mission Preparation Phase begins with release of the PASS/BFS OI loads from the development contractors. Mission specific requirements documents are developed by NASA MOD/RMD and approved by the SASCB. These inputs are integrated in the SRF into an integrated mass memory unit software load and submitted to various

operational users for mission preparation and testing including final flight operations. SRF activities are referred to as “Frontroom” activities. The mission preparation phase requires approximately nine months from the delivery of the OI loads until the first STS mission is flown using the newly developed OI capability. Mission preparation activities have two major cycles: one for the initial FSW mission reconfiguration (engineering cycle) at approximately six months prior to flight (L–161 days), and the flight cycle at approximately three months prior to flight (L–77 days). Partial updates and corrections may be applied as part of the reconfiguration process. Parallel mission preparations are performed for multiple STS missions utilizing the same FSW OI load (see Figure B–3).

5.3.1 Reconfiguration Data

The SOC personnel support NASA MOD/RMD who define the mission requirements and vehicle specific data (I–Loads), which are used to reconfigure the PASS and BFS OI baseline loads for specific missions and vehicles. SOC prepares input data for the Shuttle Transportation Automated Reconfiguration (STAR) and Measurement and Stimulus (MAST) FSW reconfiguration tools. MSFC personnel develop SSMEC software to be used with each Shuttle engine and deliver the SSME software to the mission preparation process as GFE software (Reference Appendix A). SSMEC software configuration is managed by the MSFC NASA SSP Project Office, similar to the SASCB at JSC. Reconfiguration data also includes SPF simulator initial conditions and simulation model preparation data.

Embedded V&V Activities: All I–Loads are audited by I–Load owners prior to approval and after flight cycle load build for the first flight of an OI and then for those not previously audited on subsequent flights of the OI. Simulator test conditions are provided for Lockheed Martin and Rockwell International validation (Level 8) testing. Performance tests are executed by Lockheed Martin and Rockwell International to verify the reconfigured FSW.

5.3.2 Vehicle Cargo System (VCS) Reconfiguration Data

STAR/MAST data are processed by SOC, using configuration controlled processing tools to generate the VCS software data inputs required for a mission–specific FSW load. Lockheed Martin is the operations contractor responsible for producing the IMMU loads used during an STS mission.

Embedded V&V Activities: Each contractor verifies the data source inputs, checks the resulting syntax, and verifies consistency of their individual products.

5.3.3 Reconfiguration Activities

The FSW development contractors are responsible for developing and maintaining all software tools which can affect the reconfigured FSW memory loads. At CI, these FSW build tools have completed validation and are ready for reconfiguration use.

The OI validated loads are reconfigured by the implementation of Mission/Vehicle unique data, and the VCS Recon products. Lockheed Martin reconfigures the baseline PASS OI FSW while Rockwell International reconfigures the baseline BFS OI FSW. The BFS FSW load is then delivered to Lockheed Martin for application to the IMMU.

Embedded V&V Activities: Lockheed Martin and Rockwell International perform validation (Level 8) tests on the resulting IMMU.

5.3.4 Integrated Mass Memory Unit Load

The IMMU load contains the actual flight programs cycled in the Space Shuttle GPCs and/or flight equivalent hardware used in SSP ground facilities. The PASS, BFS, etc., software are integrated by Lockheed Martin into a master IMMU load for operational use by all FSW users.

Embedded V&V Activities: The IMMU load is certified by Lockheed Martin. The IMMU load is used for validation (Level 8) tests. The IMMU load is provided to the SAIL, SMS, KSC Cargo Integration Test Equipment, KSC Avionics Test Set (KATS), Orbiter, and other FSW users for operations and/or mission testing. The SES does not receive a copy of the IMMU load but does use a FORTRAN equivalent build of the IMMU load. This FORTRAN equivalent build is independently supplied by ED.

5.3.5 Operational Validation Testing

Level 8 (Mission) testing is performed in the SPF using flight equivalent GPCs interfaced with a mainframe computer containing Shuttle math models simulating the mission conditions necessary to test the FSW. The SPF simulator conditions and math model data are built into a simulation load prior to beginning FSW testing. Level 8 testing, whose requirements are controlled by the SASCB in the Performance Test Plan, is conducted using the final (L–77) reconfiguration load which contains mission–unique I–Loads. The SPF simulation does not provide a realtime simulation of mission operations which requires scripting of test scenarios. Validation testing is performed by Lockheed Martin and Rockwell International.

Operational testing is defined as the operational use of the FSW during mission preparation (i.e., flight and ground operations training, mission procedures development, etc.) and SAIL testing. Operational testing is a realtime operation using flight equivalent and simulated flight hardware, as well as a full complement of flight computers. The SAIL,

SMS and SES all provide a flight crew interface. The entire mission is flown in the SMS during flight crew training. Problems found during operational testing are recorded in DRs, and submitted to the appropriate organization for analysis or resolution.

Embedded V&V Activity: Crew and mission operations training in the SES and SMS exercise the man–in–the–loop FSW interface to validate mission capability. SAIL is used to verify the integrated hardware/software interfaces as well as mission capability and the man–in–the–loop FSW interface testing.

5.3.6 Performance Test Reviews

The PTRs are milestones leading to the release of FSW for use in each STS mission and are administered by distributing performance test reports to the FSW community for their review and concurrence. The MOD/reconfiguration contractors are responsible for producing the performance test report which includes the results of their analysis of the Level 8 performance tests and for resolving any issues generated by the FSW community. The ED, MOD, SR&QA, and RI/D technical organizations are responsible for reviewing test result summary reports for reasonableness within their areas of accountability.

Embedded V&V Activity: The FSW technical organizations independently review the test results/analyses prepared by the FSW reconfiguration contractors for reasonableness and consistency and report the results at the SRR.

5.3.7 Flight and Software Readiness Reviews

The SRR is held approximately three weeks prior to flight. The SRR is conducted by NASA to allow all members of the FSW community to review FSW open issues relating to the software's ability to perform the planned mission. The results of the Level 8 testing are reviewed, as well as any software issues encountered during operations.

The FRR is held approximately two weeks prior to flight, with a follow up FRR held approximately two days prior to flight to resolve any remaining issues that may affect the planned mission. The FRR is held by the SSPO to allow all members of the STS community to review and disposition open STS hardware and software issues related to the planned mission. All aspects of flight vehicle preparation are reviewed and flight or mission related concerns recorded and dispositioned.

The FSW community (in particular, the ASD/FSW development contractors, ED, the crew, the MOD/reconfiguration contractors, SR&QA, and the Orbiter representatives) are responsible for supporting these readiness reviews and identifying their readiness posture to support flight.

Embedded V&V Activities: Each FSW contractor and NASA FSW organization having a role in preparation of FSW for the flight/mission is required to certify that preparations

are completed and that to the best of their knowledge there are no known problems that affect the safety of the flight or completion of the STS mission.

5.3.8 Mass Memory Dump and Compare

Five days prior to launch, the Orbiter MMUs are dumped and compared to the mission baseline load (by Lockheed Martin). All differences are analyzed and evaluated to ensure that only approved changes have been implemented in the final flight MMU. The MMUs are mass storage devices (magnetic tapes) in the Orbiter on which the IMMU load is loaded and from which the flight computers receive the FSW load for mission support.

Embedded V&V Activities: KSC transmits the dump of MMUs 1 and 2 along with a corresponding TR to JSC/MOD and the PASS FSW reconfiguration contractor identifying the dataset names of the dumps. In the event a mass memory with an anomaly is authorized to fly, KSC will send JSC a partial dump of that MMU. The MMU loads are compared bit by bit by the PASS FSW reconfiguration contractor.

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FIGURE B–1

FLIGHT SOFTWARE DEFINITION ROADMAP

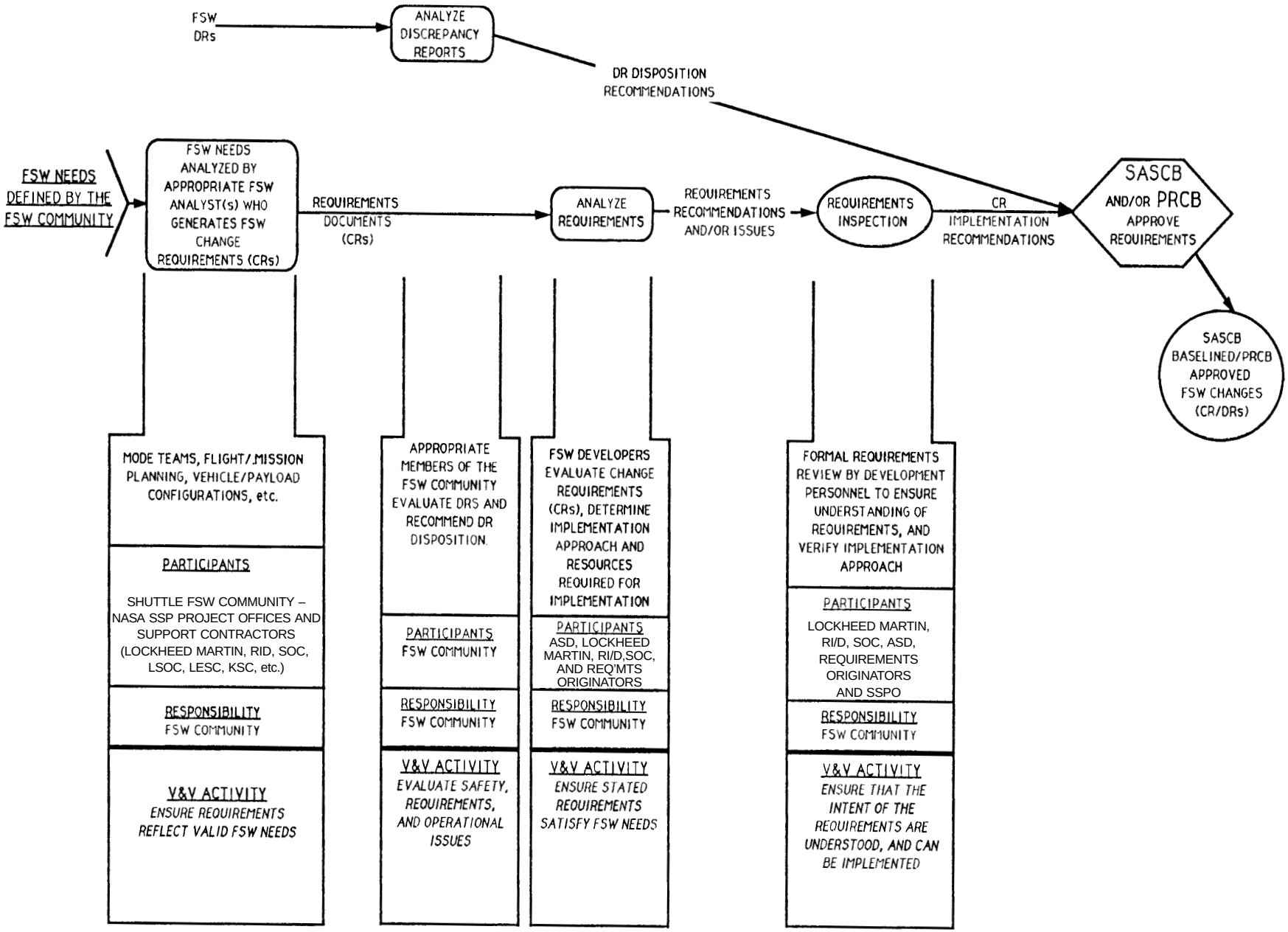


FIGURE B–2

FLIGHT SOFTWARE DEVELOPMENT ROADMAP

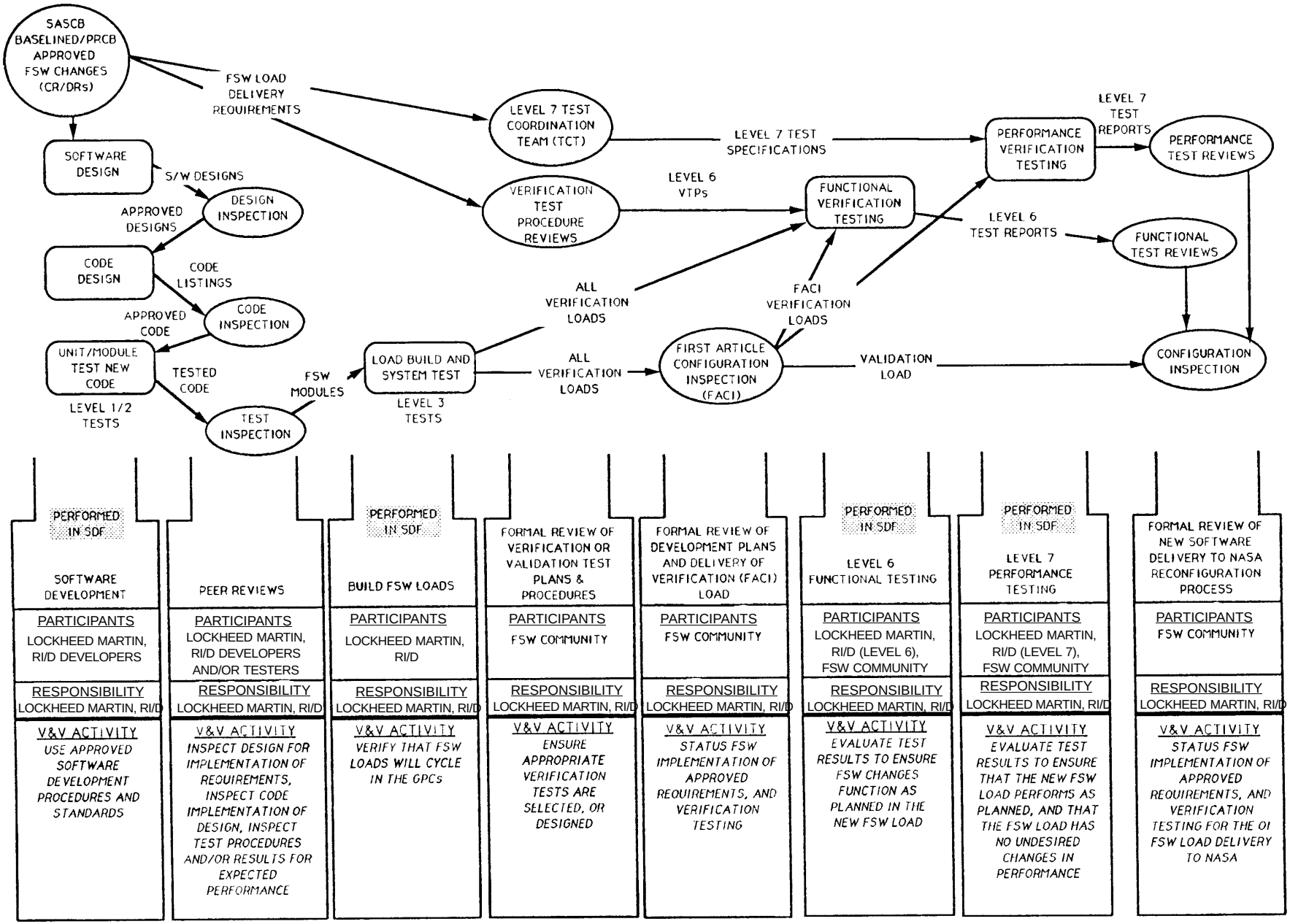
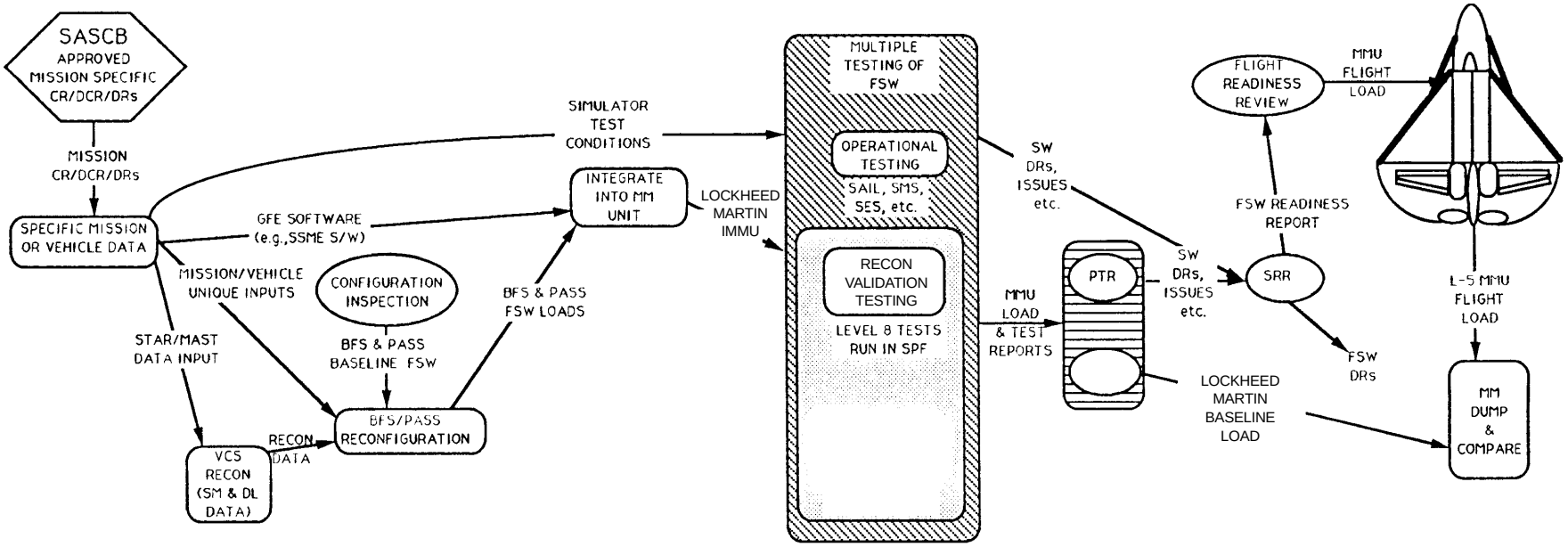


FIGURE B–3

FLIGHT SOFTWARE MISSION PREPARATION ROADMAP



PREPARE BUILD MISSION/VEHICLE BUILD DATA (STAR,MAST, SSME,etc.)	GENERATE PASS FSW BUILD DATA (SM & DL)	LORAL BUILD PASS FSW LOADS, RI/D BUILD BFS FSW LOADS, DELIVER COPY TO LORAL	INTEGRATED MASS MEMORY BUILT	RUN CONCURRENT VALIDATION LEVEL 8 TESTS, WHILE RUNNING FSW IN OPERATIONAL FACILITIES	FORMAL REVIEWS OF TEST RESULTS AND ANALYSIS OF SOFTWARE READINESS	FORMAL REVIEW OF MISSION PREPARATION AND HW/SW READINESS FOR FLIGHT	DUMP FLIGHT COMPUTERS AND COMPARE WITH THE BASELINE LOAD
PARTICIPANTS SSP ENG/PO, SOC, RI/D, LORAL, MSFC, etc	PARTICIPANTS LORAL	PARTICIPANTS LORAL, RI/D	PARTICIPANTS LORAL	PARTICIPANTS LORAL, LORAL SUBCONTRACTOR, LESC, CAE, RI/D	PARTICIPANTS FSW COMMUNITY	PARTICIPANTS FSW COMMUNITY, AND SSP	PARTICIPANTS LORAL, KSC, LESC
RESPONSIBILITY SOC, MSFC, RI/D	RESPONSIBILITY LORAL	RESPONSIBILITY LORAL, RI/D	RESPONSIBILITY LORAL	RESPONSIBILITY LORAL, RI/D	RESPONSIBILITY LORAL, RI/D	RESPONSIBILITY SSPO	RESPONSIBILITY KSC
V&V ACTIVITY *VERIFY I-LOADS FOR MISSION/VEHICLE SOFTWARE CHANGES AND REVIEW SSMEC OAD INPUTS*	V&V ACTIVITY *VERIFY SOURCE READS, CHECK SYNTAX & CONSISTENCY FOR INDIVIDUAL PRODUCTS.*	V&V ACTIVITY *LEVEL 8 TESTING BY LOCKHEED MARTIN, RI/D*	V&V ACTIVITY *CERTIFICATION OF IMMU CONTENTS*	V&V ACTIVITY *LEVEL 8 TESTS ARE EXECUTED INDEPENDENTLY BY LORAL & RI/D. EVALUATE RESULTS OF SIMULATED OPERATIONS IN THE SMS, SAIL, SES, etc. BY THE CREW AND OTHER MEMBERS OF THE FSW COMMUNITY*	V&V ACTIVITY *REVIEW THE VALIDATION TEST RESULTS*	V&V ACTIVITY *STATUS FLIGHT PREPARATION ACTIVITIES HAVE BEEN COMPLETED AND VERIFIED ACCORDING TO APPROVED NSTS STANDARDS*	V&V ACTIVITY *ENSURE THAT ONLY KNOWN AND APPROVED CHANGES HAVE BEEN ADDED TO THE ONBOARD FLIGHT LOAD SINCE THE FSW WAS APPROVED FOR FLIGHT*

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APPENDIX C

SPACE SHUTTLE MAIN ENGINE CONTROLLER BLOCK II SSME FLIGHT SOFTWARE DEVELOPMENT AND VERIFICATION AND VALIDATION

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APPENDIX C

SPACE SHUTTLE MAIN ENGINE CONTROLLER BLOCK II SSME FLIGHT SOFTWARE DEVELOPMENT AND VERIFICATION AND VALIDATION

1.0 PURPOSE

The purpose of this report is to describe the Block II SSMEC flight software development process and identify the role of embedded V&V in this process.

2.0 INTRODUCTION

MSFC in Huntsville, Alabama, is the NASA center and Rocketdyne of Canoga Park, California, is the prime contractor responsible for the Space Shuttle Main Engines including the SSMEC flight software. The SSMEC flight software, currently used in the SSP, consists of baselined software and Operational/Adaptation Data (OAD). OAD is used to customize the SSMEC software for specific engines and individual STS flights.

SSMEC software changes are released as Requirement Change Notices (RCNs), Design Change Notices (DCNs) and Code Change Notices (CCNs). Each RCN, DCN, and CCN stands alone, all information needed to define the change is self contained or is referenced. A specific change may generate any one or more of the three types of change notices. The design might be modified to comply with a preferred method of implementation that generates a DCN and CCN, but not necessarily an RCN. Each change notice contains a definition/description of the change, marked–up pages of the affected documents in the case of an RCN, and an identification of the generating discrepancy or enhancement request. An SSMEC software change will be authorized/tracked by a System Note (SN) or the associated Change Notice, which may be written due to a Unsatisfactory Condition Report (UCR).

SSMEC software is developed at Canoga Park, California, is verified/validated in the Hardware Simulation Lab II (HSL II) at MSFC, and is certified at SSC. SQA monitors the development process throughout the entire software life cycle. The software development cycle is maintained under strict configuration management control to ensure proper change control, version content and identification techniques are applied. Verification, validation and certification activities are performed prior to authorizing the software for FRF or flight. Honeywell is the subcontractor responsible for the design and development of the SSMEC hardware and provides an independent engineering assessment of SSMEC software requirement changes and verification procedures.

The SRG is a review group consisting of MSFC, JSC, KSC, Rocketdyne (Canoga Park, HSL, SSC), Honeywell and other personnel which addresses the concerns of the

SSMEC software community during the software life cycle. The SRG meets weekly via telecon and discusses the status and schedules of SSMEC software as well as SSMEC support software. The SRG also provides information of potential software changes to participants as a way of providing the SSMEC software community the visibility of potential changes early in the software life cycle. Through the SRG, the SSMEC software community provides the project with an early assessment of areas of concern and possible system impacts.

3.0 DEVELOPMENT APPROACH

There are four distinct “Roadmaps” for the current SSMEC software development process: Requirement Definition, Software Development, Verification/Validation/ Certification and Mission Readiness. The Requirement Definition Roadmap identifies the activities and related control mechanisms used to control changes to the SSMEC software. The Software Development Roadmap identifies the development contractor activities and controls used to develop change packages (RCN/DCN/CCN) at the Rocketdyne facility, Canoga Park, CA. The noted packages are paper for RCNs and electronic files for DCNs and CCNs. The Verification/Validation/Certification Roadmap describes activities and controls used to verify that the software delivered to MSFC meets requirements. The Mission Readiness Roadmap describes the activities and controls associated with ensuring that the software products delivered to JSC/KSC are ready for use with the target STS flight.

3.1 BLOCK II SSMEC REQUIREMENTS DEFINITION

Prospective changes are generated by the entire SSMEC software community. These prospective changes consist of enhancements and/or corrections to SSMEC software (requirements/design/code). SSMEC software enhancements and discrepancies are documented in SNs and, if required, UCRs. SNs are used as a mechanism to track all changes. The SN is a Rocketdyne mechanism and is generated, numbered, tracked, and maintained electronically via the Canoga–based computer networked Change Tracking System (CTS). UCRs are generated beginning at release for hotfire certification on all open discrepancies of Severity 1, 1N, 2, and 2N, as defined by RF0004–004, SSME Reliability Data Reporting Requirements. It should be noted that SNs are always paired with CLCRs for implementation. SNs may describe a specific problem or a vague situation. The CLCR contains the direction as to how the solution is to be implemented. The SNs/CLCRs are dispositioned by the Rocketdyne Software Configuration Control Board (SCCB), consisting of systems analysts, flight performance specialists, avionics integration personnel, software personnel, and SQA personnel. The disposition by the SCCB includes the method for resolution and types of changes that shall be required (requirements, design, code). The changes are then presented to the SRG for review. The requested changes are dispositioned by the SCCB as revise, approved, or

canceled. Changes requiring a revision are iterated through the SCCB until approved or canceled. Approved changes become part of a change package (RCN/DCN/CCN) and are distributed to the appropriate development group for implementation.

Embedded V&V: Rocketdyne evaluates proposed changes to ensure that the proposed changes are valid SSME change and/or SSP changes. Honeywell ensures compatibility of the software changes with the SSMEC hardware and verifies that no single point failures will be introduced by the change. The SRG review of the software changes can provide an early assessment of possible impacts to their area of responsibility. Final approval of the proposed changes for flight use are defined in the Embedded V&V section of Paragraph 3.3.

3.2 BLOCK II SSMEC SOFTWARE DEVELOPMENT

The Canoga Software Group prepare the paper/electronic change notices (RCN/DCN/CCN) which contain a description of the change. The documentation of the requested change (SN/CLCR) is also included. The software change goes through three development phases: documentation, implementation, and test. The change is analyzed and the appropriate documents updated. The change is reviewed in an informal development contractor CDR. The change is then implemented, which in the case of the RCN and the DCN, occurs when updating the documentation. The CCNs are coded and the SSMEC Software is then compiled. The CCNs are tested at the Canoga Software Laboratory. The change and the software including the change, if applicable, are delivered to HSL II for Verification Test.

Embedded V&V: Personnel from Software, Avionics, Engine Systems and SQA review the change package to ensure that the intent of the change is understood and can be implemented correctly. Rocketdyne ensures that all modifications to the SSMEC software are compatible with the current SSME and Block II SSMEC hardware. Rocketdyne verifies that the design correctly implements the requirements. The code is inspected and analyzed to ensure the design is implemented properly and efficiently. SSMEC software integration test results are reviewed and problems encountered during test are corrected and the software is retested. Rocketdyne Canoga Park verifies that all development activities have been completed. Honeywell SSMEC Systems Engineers review the requirement change package to ensure that the modifications are compatible with the SSMEC hardware and that no single point failures are introduced. SQA monitors SSMEC software activities throughout the development life cycle. The SSMEC software is maintained under configuration control.

3.3 BLOCK II SSMEC VERIFICATION/VALIDATION/CERTIFICATION

SSMEC software verification is conducted in the HSL II at MSFC and software certification is conducted on the engine hotfire test stand at SSC. Changes (RCN/DCN/CCN)

are delivered to Rocketdyne HSL personnel at MSFC, who review the changes. Test procedures are generated and/or modified to verify the new requirements or design changes. An Executable Image Compare (EIC) is performed following each compilation which includes logic changes. This compare, against a known base, is used to verify that only the intended software modules were affected and to assist in identifying areas of retest. Each change is then verified in the HSL II. All discrepancies found during the verification process are reported on a SN. Complete, post verification change packages are provided to the SSMEC software community. Rocketdyne at Canoga Park prepares a Hotfire Simulation Request Package that specifies the software configuration, test profile, and special tests, as required. The hotfire simulation and special tests are performed at the HSL II. In addition, a Data Base Compare is performed on the software that is to be used for engine hotfire test. Upon completion of these tests and approval by MSFC, the software is authorized for engine hotfire test at SSC. Engine hotfire tests certify the SSMEC software.

Upon completion of the software certification and approval of the ECP and the associated Verification Complete Package (VCP) by MSFC, the software is then acceptable for STS flight. A SSMEC software delivery, with the appropriate OAD incorporated, is prepared for the STS flight. The software configuration is verified by Rocketdyne and MSFC to be the configuration required by the FEC. This SSMEC software delivery, including the FEC and the SAN is authorized by MSFC for specified functions: check–out, FRF, and flight. A complete delivery is made when changes to OAD are required or when new changes are approved, requiring a Code Change Notice (CCN). Upon release of a SSMEC software delivery by MSFC, the SAN and FEC receives final authorization for use at JSC and KSC by the SASCB.

Embedded V&V: The test procedures are reviewed by Honeywell and/or peer review. SQA monitors the testing at HSL to ensure correct results and reporting of any discrepancies. Hotfire simulation results have two separate reviews prior to submittal to Engine Systems/Software. Data Base Compare results are verified to be correct by review against the data Version Description Document (VDD). MSFC verifies that verification is complete prior to the use of the software for engine hotfire. Verification/ delivery software and procedures are maintained under configuration control.

MSFC approves logic changes for flight via an ECP and changes for a specific STS flight by FEC. MSFC approval is documented by a Configuration Change Board Directive (CCBD).

The review by Rocketdyne and MSFC assures that the software delivered for STS flight is correct and complete and that the software meets any unique requirements.

3.4 BLOCK II SSMEC SOFTWARE MISSION READINESS ROADMAP

JSC SASCB receives the change packages (RCN) from MSFC. The SASCB then reviews and provides technical concurrence of the change. The SASCB does not approve change packages; however, as the SSPO, they concur that the change package is technically required, and acceptable for use in the FSW. As OAD and software updates are approved for STS use, MSFC delivers a complete re–compiled version of the SSMEC software. When MSFC delivers SSMEC changes, the appropriate SSME configuration is also provided. The SSME configuration is used both to configure the FSW, and establish test conditions in the SAIL, if appropriate. Once the SSMEC software is delivered to JSC/KSC, it is included in SAIL Avionics Integration testing and is considered at all STS mission FRRs/SRRs. If a SSME capability has been modified, or expected operational environment has changed, the test environment (JSC tools such as SPF, SAIL, SMS SSME hardware and/or performance simulation models) may have to be modified.

Integration testing is defined as the operational use of the SSMEC FSW during mission preparation testing in the SAIL. Integration testing is a realtime operation using flight equivalent and simulated flight hardware, as well as a full complement of flight computers. The SAIL provides a flight crew interface. Operational avionic system hardware/software integration test scenarios and mission scenarios are performed at SAIL. Problems found during testing are recorded in Interim Discrepancy Reports (IDRs) and submitted to the appropriate organization for analysis or resolution.

MSFC delivers both the operational software and the compare software to JSC/KSC either by tapes or electronically.

The FRR is held approximately two weeks prior to each flight or FRF, with a follow up FRR held approximately two days prior to each flight or FRF to resolve any remaining issues that may affect the planned mission. The FRR is held by the SSPO to allow members of the STS community to review and disposition open STS hardware and software issues related to the planned mission. All aspects of flight vehicle preparation are reviewed and flight– or mission–related concerns recorded and dispositioned.

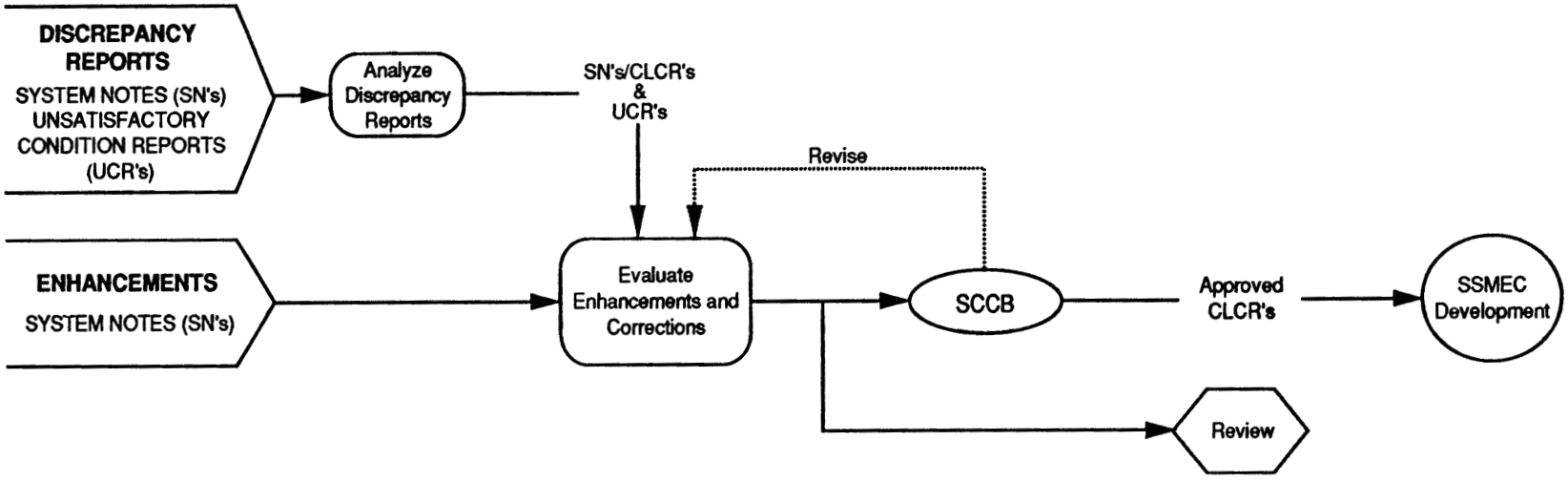
Embedded V&V: The software builds are validated through bit by bit tape comparisons. SSMEC software is exercised in the SAIL. When changes are made to test tools, the simulated hardware and/or performance operational data is verified against the real world. Tests in the SAIL are avionics integration tests performed under sponsors from the FSW community. Specific tests are not performed in the SMS; however, Flight Crew training usually exercises the full range of missions operations, and a subset of off–nominal operations which have the potential of occurring during the mission. Any discrepancies encountered during SMS training or SAIL testing, are documented in DRs.

The use of the compare software and/or the internal SSMEC sum check to verify the SSMEC software load, verifies the SSMEC was loaded correctly.

Each contractor or NASA organization having a role in preparation for the flight and mission is required to certify that preparations are completed and that to the best of their knowledge there are no known problems that affect the safety of the flight or completion of the STS mission.

FIGURE C–1

BLOCK II SSMEC SOFTWARE REQUIREMENTS DEFINITION ROADMAP



Review SN's/CLCR's, Prepare UCR's, Evaluate UCR's and Prepare Recommendations	Recommend Generic and Specific Modifications and/or Enhancements Based Upon Rocketdyne Engine System Studies or Other SSMEC SW Community Needs	Review Changes Proposed and Disposition as Revise, Cancel or Approve	SRG Reviews Problems Addressed to Rocketdyne Engine Systems
PARTICIPANTS SSMEC SW Community	PARTICIPANTS SSMEC SW Community	PARTICIPANTS Rocketdyne Engine Systems, Software, Avionics and SQA	PARTICIPANTS MSFC, JSC, KSC, SSC, Rocketdyne and Honeywell
RESPONSIBILITY Rocketdyne Engine Systems Group	RESPONSIBILITY Rocketdyne Engine Systems Group	RESPONSIBILITY Rocketdyne Engine Systems Group	RESPONSIBILITY MSFC
V&V ACTIVITY *Ensure Discrepancies Are Valid*	V&V ACTIVITY *Ensure That Enhancements Reflect Valid SSME Systems Changes or Program Needs*	V&V ACTIVITY *Ensure Change Requirements Are Valid and Needed*	V&V ACTIVITY *Evaluate Requirements and Operational Issues*

FIGURE C–2

BLOCK II SSMEC SOFTWARE DEVELOPMENT ROADMAP

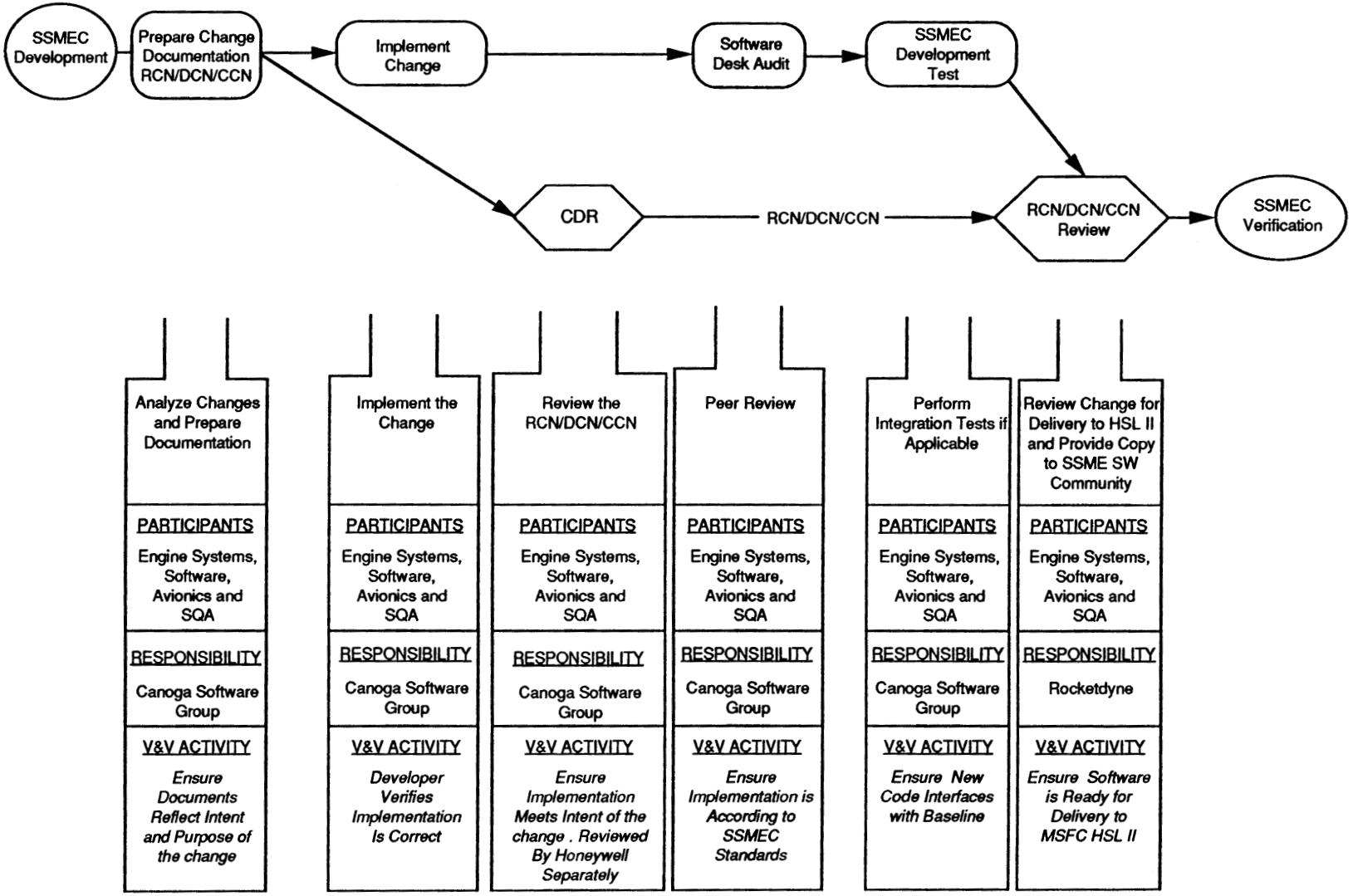


FIGURE C–3

BLOCK II SSMEC SOFTWARE VERIFICATION/VALIDATION/CERTIFICATION ROADMAP

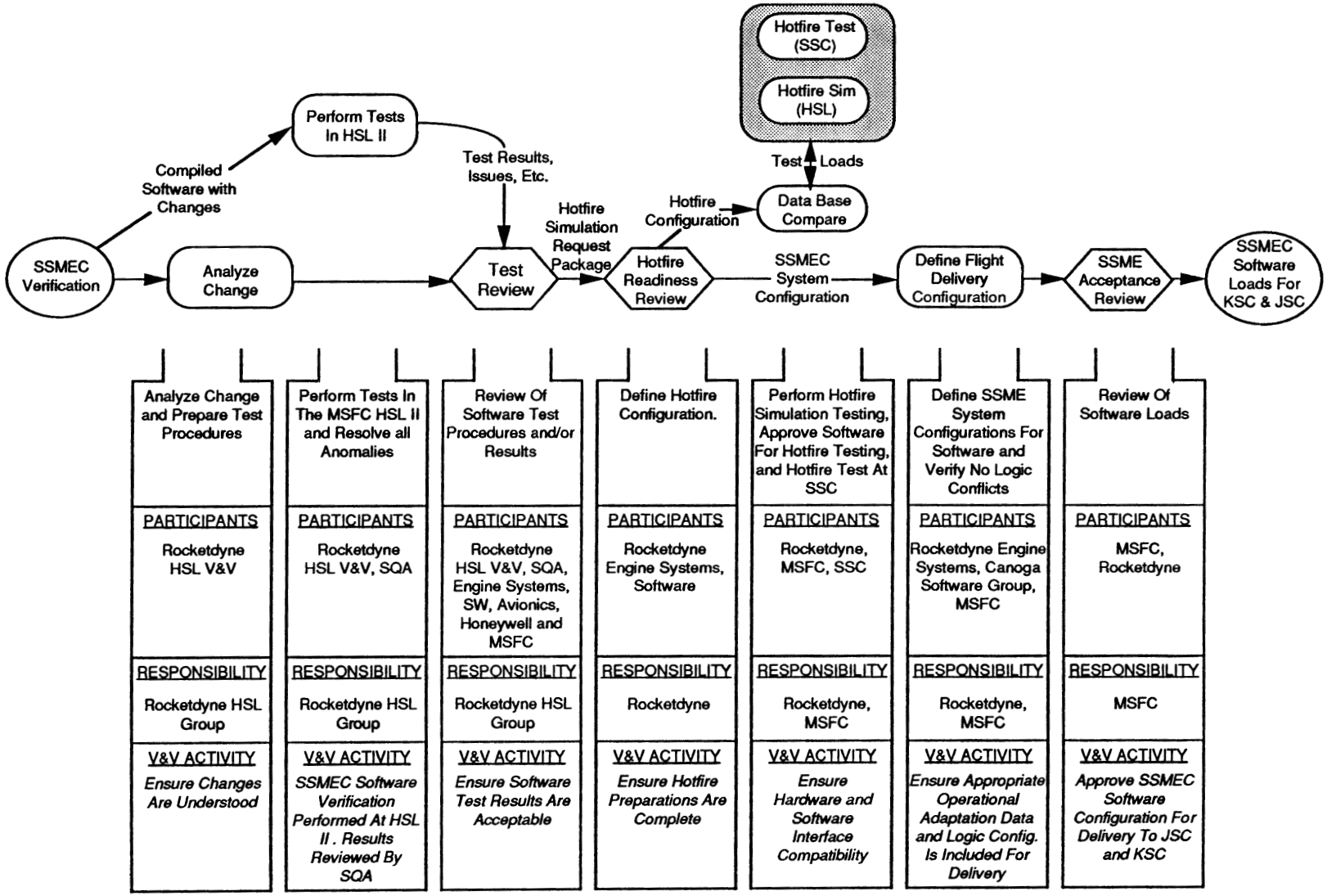
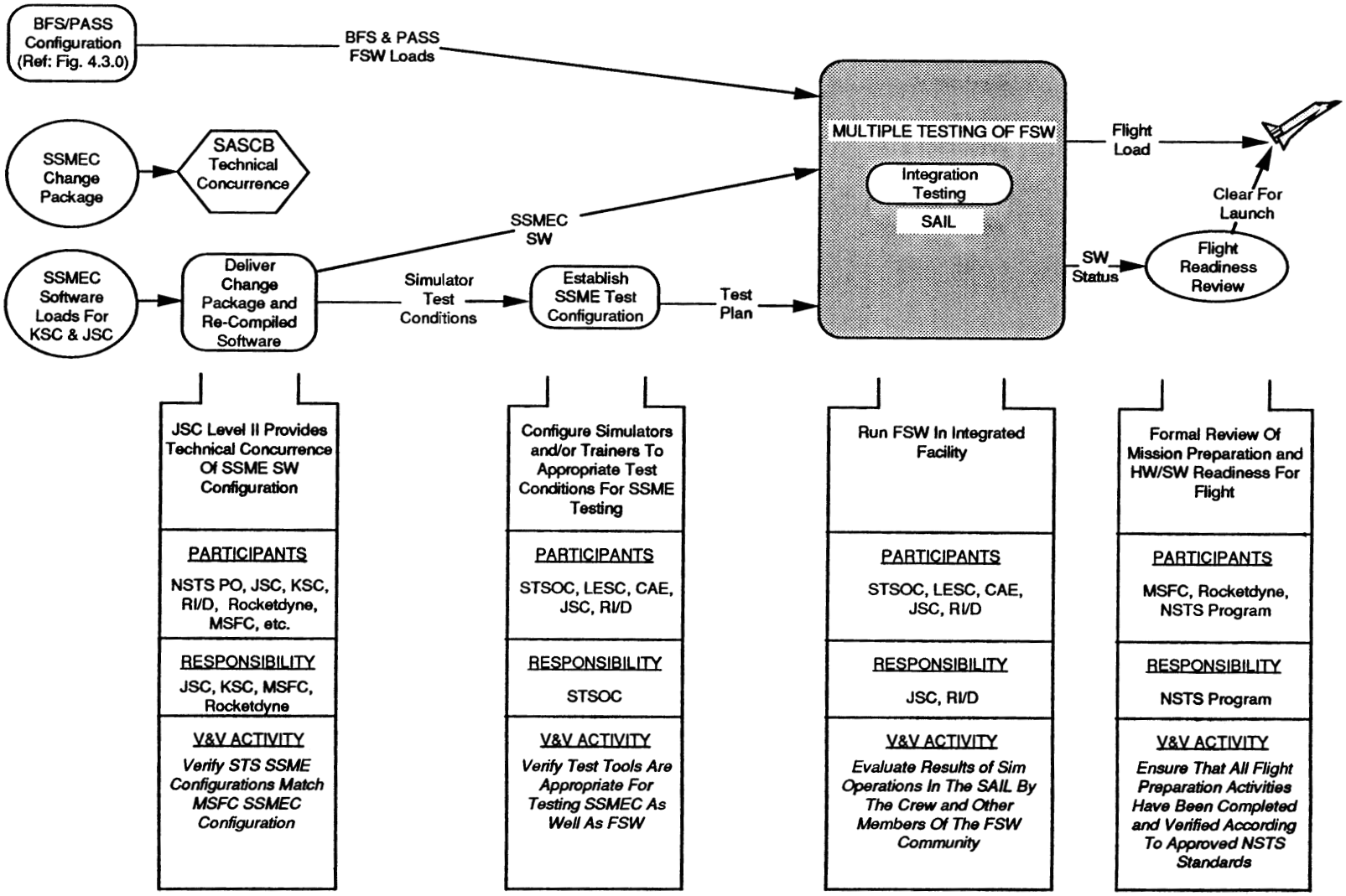


FIGURE C–4

BLOCK II SSMEC SOFTWARE MISSION READINESS ROADMAP



APPENDIX D

KSC GROUND SOFTWARE
VERIFICATION AND VALIDATION DOCUMENT

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APPENDIX D

KSC GROUND SOFTWARE VERIFICATION AND VALIDATION DOCUMENT

1.0 PURPOSE

The purpose of this document is to define the Space Shuttle Program requirements for KSC Ground Software V&V Process and to establish the activities and the responsible elements in this process for Checkout, Control, and Monitor System (CCMS) System Software, Vehicle and Ground Support Equipment (GSE) CCMS Ground Application Software, Payload Ground Operations Aerospace Language (GOAL) Ground Application Software, and Facilities Control Application Software. This baselines the V&V process utilized for requirements definition, and software development.

1.1 VERIFICATION AND VALIDATION

Embedded V&V of Application Software is a process used at KSC to satisfy the intent of the recognized procedure of Independent Verification and Validation (IV&V) of software. The embedded V&V process allows verification and validation to be performed within the same organizational structure of a company/contractor. Usually this process functions such that the software developing group/section/office is under a different manager than the groups/section/office performing V&V. When this is not organizationally reasonable, strict rules/guidelines are adhered to, in addition to normal configuration management and quality controls, to ensure total software integrity and reliability.

At KSC, for application software, the V&V process tends to meld into one process which is addressed as verification. V&V is performed against Math Models and not flight hardware. Once released for use against flight hardware the V&V process is effectively complete. During the day–to–day use of application software, the user team will document all software problems. This action can be considered an endless validation cycle.

2.0 APPLICABLE REFERENCES

NSTS 07700 Volume XVIII Book 3	Computer Systems and Software Requirements, Software Management and Control
NSTS 07700 Volume IV	Configuration Management Requirements

3.0 INTRODUCTION

KSC Ground Software is defined and developed by the KSC Ground Software community. Prime members of the Ground Software community are:

a. NASA Vehicle Engineering/TV – Responsible for Vehicle and GSE CCMS Ground Application Software

b. NASA Ground Engineering/TE – Responsible for CCMS System Software and Non–Base Operations Contractor (BOC) supported Complex Control Set (CCS) Facility Control CCMS Ground Application Software

c. NASA Center Support Operations/SI – Responsible for the BOC portion of CCS Facility Control CCMS Ground Application Software

d. NASA STS Payload Operations/CS – Responsible for CCMS Payload Ground Operations Application Software

Each NASA function has its supporting contractor.

a. Shuttle Processing Contractor (SPC) – Responsible for Vehicle and GSE CCMS Application Software, CCMS System Software, and the non–BOC portion of the CCS Facility Control CCMS Ground Application Software requirements definition, development, and verification and validation

b. Base Operations Contractor (BOC) – Responsible for the BOC portion of the CCS Facility Control CCMS Ground Application Software Requirements definition, development, and verification and validation

c. Payload Ground Operations Contractor (PGOC) – Responsible for CCMS Payload Ground Application Software requirements definition, development, and verification and validation

The NASA Safety, Reliability, and Quality Assurance (RQ) Directorate maintains involvement with the software development process but has delegated their direct V&V activities to the cognizant NASA directorates.

It is intended that this document will address the various types of KSC Ground Software at a level that will present, as a single process, the KSC development and V&V flow. The types of software covered in this document are limited to that software which runs in the CCMS Control Rooms 1 through 4, Cargo Integration Test Equipment (CITE), Hypergolic Maintenance Facility (HMF), and the CCS. The CCMS System Software is also included as it is the operating environment of the CCMS sets which supports the execution of the application software.

While each Ground Software Development Contractor functions independently of each other, the development and V&V processes of software are basically the same. Engineering requirements, in the form of design center change paper, are received and

assessed for impact to the applicable software. The change package for implementation is assembled, reviewed and approved at the applicable change board. The approved implementation package is provided to the implementing group for action. During code development, embedded V&V activities ensure that the approved change is correctly incorporated. After internal verification by the developer, the change is formally verified using an approved verification plan or procedure. Only after successful verification under the approved verification plan and configuration audit will the revised software support hardware testing and operations.

It should be noted here that CCMS Application Software is written in a unique language. The GOAL was developed as an engineering tool to support the implementation, in an automated fashion, of Operations and Maintenance Requirements Specification (OMRS) test requirements which, due to safety requirements and/or test timing and complexity, do not lend themselves to manual performance.

While the CCMS Application Software, which automates OMRS test requirements, is necessary for successful completion of the test or launch, this software is of a less critical nature than JSC–developed flight software. CCMS application software always operates in a mode where engineering personnel are monitoring the performance of the test and the performance of the software. These engineers stand ready to terminate the test or declare a test invalid should the application software not perform to requirements. Flight software, on the other hand, must operate in the background without constant manual test monitoring and operator intervention.

For high energy hazardous systems V&V will always include a verification of interfaces to other programs or systems in addition to the verification of the incorporated change. A change to a safing program, e.g., control logic, requires the total verification of the program as well as verification of interfaces with other programs. Ground Launch Sequencer (GLS) changes will always include a total set run prior to use during a launch countdown.

4.0 KSC GROUND SOFTWARE COMMUNITY

4.1 VEHICLE ENGINEERING/TV

The Vehicle Engineering Directorate is responsible for the management and direction of the engineering aspects of integration, test, checkout, documentation, launch preparation, turnaround operations, and analysis of operational performance as they relate to the total Shuttle Vehicle Systems, and launch and landing GSE during KSC processing, including Level I payload integration. To accomplish this assignment, the Vehicle Engineering Directorate is also responsible for the training and staffing of the Engineering Launch Teams in the use and support of the Launch Processing System (LPS), providing engineering support at various off–site factories and development test facilities,

and negotiating with development centers for approval of test and operational sequences, methods, and standards.

V&V Role: The Vehicle Engineering Directorate has responsibilities for the CCMS computer applications software aspects of LPS, which include test, checkout, simulation application, system engineer training, and documentation for associated ground checkout and flight computer interfaces. The Directorate manages and/or participates in the development, integration, verification, and validation of all software programs required for onboard Test Control Supervisor (TCS) sequences and ground test checkout, flight and GSE simulations, and systems GOAL Applications and Control Logic applications routines. The Computer Software Branch, by way of confirming V&V, participates in Shuttle, LPS, and GSE checkout by monitoring tests, evaluating data and performance.

4.2 GROUND ENGINEERING/TE

The Ground Engineering Directorate manages activities of KSC electronic systems and STS processing facilities, as well as related systems and equipment. The Directorate is responsible for the LPS, which includes all CCMS utilized in control room operations, the large–scale Shuttle Data Center (SDC) computer system, and the Record and Playback System (RPS). Incumbent to the management of assigned systems, the Ground Engineering Directorate performs design, development, sustaining engineering, implementation, operation and maintenance for LPS, and related support equipment. This Directorate performs operations and maintenance planning and operation of all LPS sets, both hardware and software, as well as hardware and software sustaining engineering.

V&V Role: The Launch Systems Engineering Section, TE–LPS–21, assumes the directorate's responsibility for the software activities, i.e., systems engineering, requirements definition, analysis, design, development, verification, troubleshooting, documentation, and configuration management involved in the sustaining engineering of Launch Systems software. This section has implemented various independent validation processes that ensure developed software fully meets its intended requirements. Section personnel have been delegated signature authority to review and approve test and validation plans generated during the software development life cycle. The Electrical and Mechanical Systems Branch, TE–FAC–3, manages the development of CCS–resident Applications Programs under its purview. All developed programs must pass a validation plan to ensure the software meets documented requirements.

4.3 CENTER SUPPORT OPERATIONS/SI

The Center Support Operations Directorate provides assigned base operations, maintenance, sustaining engineering and center support services for all KSC and tenant

organizations on the John F. Kennedy Space Center. The directorate has overall center responsibility for security, law enforcement, fire protection, industrial labor relations, administrative equipment management, energy management, emergency preparedness and supply, and transportation policies. The directorate is responsible for the following assigned systems: propellant logistics, life support, electrical and mechanical systems, administrative communications, administrative computers, and potable water and sewage systems. Within the SI area of responsibility is the control of systems with direct involvement with Shuttle hardware activities. These include pad water, electrical power, and support pneumatics.

V&V Role: The SI Directorate's involvement with V&V comes in the electrical, mechanical, and water and sewage systems that are monitored and/or controlled from the CCS. The SI Directorate is concerned with the satisfactory operations of these systems, including both hardware and software. The ground software development contractor is then charged with ensuring that specified requirements are understood, properly coded according to approved development standards and tested with the field hardware.

4.4 SHUTTLE PAYLOAD OPERATIONS/CS

The Director, Shuttle Payload Operations, is responsible for the engineering and operations management and direction of integration, checkout, maintenance, servicing and integration of Shuttle processed payload elements and experiments including mid–decks. In the area of checkout, the Shuttle Payload Operations Directorate is responsible for the CCMS payload application software development process and payload testing in the CITE. The development process consists of requirements definition, coding, debugging, verification, and validation. When this process is complete, payload testing with the applications software begins. After CITE payload testing is complete, the application software is transferred to the LCC Control Room Test Configuration Identifier (TCID) document for on–line payload testing with the Orbiter.

If the payload does not go through CITE, the payload application software is still developed in the CITE facility with the same requirements as payloads which go through CITE. When development is complete, the software is transferred to the Control Room TCID to support the Payload to Orbiter interface testing.

V&V Role: The CS Directorate has the responsibility for the verification and validation of the payload CCMS application software. The V&V is performed by the PGOC contractor and the CS system and software engineers. The application software is not used in the V&V process; instead, the application software is verified by the V&V process and then approved by the CS Software Control Board. Prior to the CS Software Control Board approval, the payload application software is reviewed and approved by the CS system and software engineers. Also, any changes to the application software are approved by the CS Software Control Board and CS and contractor engineers.

After V&V of the payload application software is complete, the software is released to the CITE set for payload testing.

When CITE testing is complete, the software is released to the Lockheed Space Operations Company (LSOC) Control Room TCID for Payload to Orbiter interface verification testing. The release of the software to CITE and the FR is approved by the CS Software Control Board.

4.5 SAFETY, RELIABILITY, & QUALITY ASSURANCE/RQ

The Safety, Reliability and Quality Assurance Directorate is responsible for establishing policy which assures the safety of personnel and the vehicle; reliability and quality of Ground Support Equipment, software and associated documentation. The RQ directorate performs a safety review of KSC generated Engineering Support Requests (ESRs) and hazardous Operations and Maintenance Instructions (OMIs). This activity provides insight into the software activity relating to these two products.

4.6 SOFTWARE DEVELOPMENT CONTRACTORS

4.6.1 Shuttle Processing Contractor

The SPC is tasked with overall processing responsibility for the Orbiter, External Tank, and Solid Rocket Boosters. This processing responsibility encompasses the processing flow from landing through launch. Also included is the responsibility for design, engineering support, maintenance, and operation of GSE. The SPC also supports the sustaining engineering, operations and maintenance of the CCMS. The SPC, as part of their processing responsibilities, is tasked with the development, maintenance and verification of CCMS application software. This software, once verified, resides in the CCMS set supporting flow processing. This application software is utilized to support vehicle deservicing and checkout in the Orbiter Processing Facility (OPF) as well as integrated Space Shuttle Vehicle (SSV) testing in the Vehicle Assembly Building (VAB) and Pad. The HMF is also supported by SPC developed software. In addition the SPC is responsible for the development of application software for support of select Launch Complex 39 systems. This software runs in the CCMS Set identified as the CCS. Part of the SPC's role is the development and sustaining engineering of the CCMS System software. This software provides the environment within the CCMS system which supports the execution of the appropriate application software.

V&V Role: The SPC, as a software developer, has the responsibility for ensuring that the software design is per approved standards and that the developed software meets the intent of the approved requirements. To accomplish this, the SPC, in conjunction with the NASA customer, has established procedures to guide the verification/validation activity. This verification/validation activity is performed by people other than the actual

software developer and utilizes an approved procedure to address the specific software change undergoing test.

4.6.2 Payload Ground Operations Contractor

The PGOC is tasked with payload processing upon arrival at KSC and continuing to launch. This includes the responsibility to maintain specific CCMS Application Software. A particular development flow is initiated, depending upon the origination of the software requirements. This happens one of two ways:

a. A new program is presented with a Payload Application Software Definition (PASD) and a Software Requirements Document (SRD).

b. A SCR is presented to make changes to an existing program.

These requirements must meet the NASA customer's approval before any changes are actually made.

V&V Role: The software is developed and supported with the approval of the NASA customers. The software engineer codes and debugs. Verification occurs using an approved Software Verification Plan. All interfaces between ground software and flight software are validated. When the verification and validation process is complete, the software is released for testing at CITE and/or to the control rooms. Any software discrepancies identified during testing are tracked and recorded via Problem Reporting and Corrective Action (PRACA) documents (Interim Problem Reports [IPRs], Problem Reports [PRs], Discrepancy Reports [DRs], or new Software Change Requests [SCRs]).

4.6.3 Base Operations Contractor

The BOC is responsible for the operations and management of high voltage power; Heating, Ventilating and Air Conditioning (HVAC); water and waste; and pneumatic systems. They also provide maintenance, design and engineering support for Kennedy Space Center utilities, facilities, certain technical and administrative operations, health, fire, and security services. The BOC provides base operations and assists flight–hardware processing to meet mission goals, supports and participates in some aspects of the KSC test or launch cycle. The BOC provides 24–hour monitoring and control of 60 HZ power, HVAC, water and waste, and pneumatics systems for the KSC Industrial area facilities, including PGOC facilities, some facilities in the LCC area, such as the HVAC chillers in the Utility Annex, and Pneumatics operations in the Converter Compressor Facility (CCF). The BOC, as part of the monitoring and control services, is tasked with the development and verification of CCMS application software pertaining to BOC and PGOC facilities and equipment. This software, once verified, resides in the CCMS Set identified as the CCS.

V&V Role: The BOC, as a CCMS software developer, has responsibility for ensuring the software design is per approved standards and the developed software meets the intent of the approved requirements. To accomplish this, the BOC, in conjunction with the NASA customer, has established a CCS Software Verification Procedure to guide the verification activity. The verification is performed, utilizing the approved verification procedure, by a software analyst other than the one who developed the software.

5.0 DEVELOPMENT APPROACH

The generic development approach utilized at KSC for Ground Software Development is a two–process approach. The first is the documenting and approval process. It includes documentation changes and the identification of driving requirements and the assessment and approval of the software implementation. The second process is the actual code development, debug, and verification activities. Also addressed in this document is the software procedure that covers those activities which take a subset of all verified software and builds a software package for loading in the applicable CCMS control room in support of scheduled activity.

5.1 GROUND SOFTWARE REQUIREMENTS DEFINITION PROCESS

The Ground Software Requirements definition process is a traditional process where requirements are provided to the ground software development contractor for action. The configuration management system operated by that contractor ensures assessments are made by all impacted functions. These assessments are processed through a control board where implementation authority is provided. The requirements are implemented and upon completion the system reports closure of the specific approved work item (see Figure D–1).

5.1.1 Requirements Identification

Requirements arrive at KSC from the various program design centers. These centers include KSC for GSE which is under KSC engineering control, JSC and MSFC for vehicle requirements, and JSC, other centers, and customer inputs for payload related requirements. These design center requirements are entered into the appropriate ground software contractor's Configuration Management (CM) system. Within the specific contractor's CM flow, each requirement is screened to identify which functional areas might be impacted by the change. This screening authority defines which engineering groups need to assess the change for specific impacts.

5.1.2 Requirements Analysis

Each impacted engineering group affected by the new requirement will perform a detailed assessment of the change to identify specific impacts to their Ground Software.

The assessment is generally by a team comprised of the hardware engineer (software user), software engineer (software developer), and their NASA counterparts. This team will analyze the existing software requirements and identify specific changes necessary in the software requirements to incorporate the new design center change. During this assessment period, the assessing engineers ensure that the new requirements are clear and concise so that the software requirements can be developed. When required for vehicle OMRSD driven changes, the Level III Launch Support Services (LSS) representative will review and sign application software requirements changes.

Embedded V&V Activity: The V&V process begins with the engineering analysis performed during the creation of the new or updated software requirements. The team, both NASA and contractor, during the review process validate the correct interpretation of the design center requirements into what will become the approved software requirements which will be utilized to develop the necessary code. This is accomplished by the comparison of the design center requirement to the software requirement.

5.1.3 Requirements Approval

The impact analysis may require impact assessments by more than one system for any given design center driven change. The analysis process results in specific impacts driven by the design center change for those impacted systems of a given ground software development contractor. These impacts are assembled into an implementation change package which is presented to a Configuration Control Board (CCB) for review and implementation approval. This board is typically made up of both the software user and the software developer. NASA also is a voting member of the SPC and PGOC CCBs. The CCB will review an assembled implementation change package for completeness, assessment by all impacted parties, and correctness of the implementation approach as defined by the new or updated software requirements. The CCB also reviews implementation effectivity when applicable to ensure hardware and software changes are synchronized. The CCB will then either approve the change package for implementation or defer the package for additional assessment or clarification of included assessments. The CCB may disapprove the implementation of the design center change into KSC ground software. These disapprovals might happen for cases where the change is a one time change which can be monitored safely by some means other than software. Once approved, the CCB–signed implementation change package will be provided to the identified implementation groups as work authorizing documents.

Embedded V&V Activity: Another step in the V&V process is the CCB's review of the submitted implementation change package which provides an independent review of the developed software requirements, ensuring that the implementation plan is in fact meeting the intent of the requirements.

5.1.4 JSC Requirements Review

Specific changes to CCMS Application Software which implement Launch Commit Criteria (LCC) for the vehicle or design requirements changes to the KSC GLS Requirements Document will require JSC assessment. Design Requirements which impact critical control software used in direct support of hazardous integrated processing for cryogenic loading of the external tank and hypergolic loading of the Orbital Maneuvering Subsystem and the Reaction Control Subsystem (OMS/RCS) will also require review. During the approval process, KSC sends these changes to JSC. These changes are assessed under the auspices of the SASCB. After the SASCB review, JSC notifies KSC of the approval. The software, once the development process is complete, will not be used until the change has been approved by the SASCB.

Embedded V&V Activity: The change review by the JSC SASCB results in a comparison of the design center requirements and the software implementation requirements. This review is intended to help ensure that the design center requirements were understood by the KSC implementation ground software development contractor and their NASA customer. Questions are coordinated with KSC by the SASCB for resolution prior to JSC SASCB approval of the change requirement interpretation.

5.2 GROUND SOFTWARE DEVELOPMENT PROCESS

The CCMS Ground Software development process involves developing code to incorporate approved requirements; performing verification to establish consistency of software documentation and code with respect to software standards, procedures, practices, and requirements; and performing V&V to demonstrate the compliance of software programs with established functional and performance requirements and system objectives (see Figure D–2).

5.2.1 Design And Code

Upon receipt of the CCB–approved implementation package, the implementing group under the appropriate Ground Software Development Contractor will proceed with the incorporation of approved requirements into the identified application program(s) or the system software module(s). During this process, the developer will review the current software to identify the best solution for the implementation of the requirements while ensuring that existing capabilities are not impacted.

Requirements may be implemented in two ways. Note that these two methods are not mutually exclusive; that is, a combination of the two methods may be selected to meet some requirements. First, new software may be developed where none previously existed. Alternately, existing software may be modified to meet the new requirement(s).

If a modification to existing software is deemed most appropriate, the developer will accomplish a “library checkout” of the revision of the software to be modified from the

controlled library. The term “library checkout”, as used here, indicates that a copy of the existing revision is obtained, while the existing revision remains in the library under full CM control. This checked–out copy will be the starting baseline for the change which is being implemented.

During the design and code process, the developer will make the necessary code changes as required to incorporate only the approved change. The developer will perform informal code compiles as necessary to verify that the changes made will pass the syntax and other rules imposed by the compiler.

During this process, the developer will perform informal debug activities utilizing developers tools and the software development set which is supporting this effort.

The developer, as part of the development process, will define the necessary changes to as–built specifications and user guides which are applicable to the software in work. These documentation revisions are processed so as to be available at the time the software will be released. Document changes are approved as outlined in Paragraph 5.1.3 and are placed under CM control.

Embedded V&V Activity: During the development process, the developer may work with their supervision and peers to obtain their review of code changes implementation. Depending on complexity of the change and experience of the developer, this V&V activity will range from a peer code review to discussions with the developer’s technical lead. The purpose of this activity is to ensure that approved coding standards are utilized and the code changes comply with the approved change package. These areas are also addressed throughout the total V&V activity from initial development to formal verification and software release.

5.2.2 Development Testing

Upon completion of the design and code phase, and prior to formal verification, the software development group will perform a structured development internal test of the completed software change. This test will follow a prepared plan and be performed in a “user like” configuration. The tests performed are the developers final confirmation that the change has been incorporated correctly and the approved requirements have been met. At the successful conclusion of this development test (100% debugged), the revised software is deemed ready for formal verification. Formal CM controls are then placed on the new revision.

NOTE: For BOC CCS software, the formal CM controls are placed on the new revision at the completion of verification.

Embedded V&V Activity: This is the point in the life cycle of this software revision where the transition from development to the formal V&V process occurs. This test

activity is the last verification by the developer that the change has been correctly implemented, to the best of their ability. The next levels of V&V will be formal and will be performed by personnel other than the actual software developer.

5.2.3 Verification Test Procedure Development And Review

The formal verification of software revisions requires the development of formal verification plans or procedures. The plans/procedures are developed by the verifying agency. This will not be the actual developer of the software, but a person or group familiar with the requirements which drove the change and who is responsible for its verification. For application software, it can be the system engineer who developed the software requirements or another software developer. For system software, it will be the independent validation group which is dedicated to this function.

The verification plans are developed to fit a standard format. This format ensures the effectiveness of the plan and drives a standard approach to verification.

The plans are developed to verify three basic areas:

a. The change was correctly implemented as defined by the approved requirements.

b. The existing software functionality was not altered.

c. The interfaces between the revised software and other programs or software sets are performing as intended.

Where the software performs critical timing functions, the verification plans may require verification that the timing functions still are performing per requirements. Evaluation of the verification plans may dictate that formal regression testing or integrated system testing must be performed.

These plans are reviewed and approved by the applicable Ground Software Development Community, both contractor and NASA, to ensure that the plan will completely perform the verification of the software.

Embedded V&V Activity: The development of the verification plan starts the formal verification process. The plan, developed independently of the software, controls and directs this effort. The completion of the plan becomes a major part of the historical audit trail of the verification.

5.2.4 Functional Verification Testing

The term functional verification testing defines that testing which is performed to verify the implemented change functions as the software requirements directed. Testing is

performed in a configuration management controlled environment. The software is placed under control before testing commences and the platform supporting the test is of a known and controlled configuration. This requirement is to ensure that the test results provide the confidence in the software that is needed prior to its being released to support hardware testing.

The testing will be performed with both NASA and contractor personnel involvement. Contractor software quality personnel will also support this activity. At the discretion of NASA and Software Quality, the V&V of software may occur without the witness of either party. All involved key personnel will sign test completion documentation reflecting successful test completion. The actual performance of the testing will be the step–by–step completion of the approved verification plan.

Embedded V&V Activity: The functional verification testing is the heart of the V&V process for ground software. While this activity is performed by the same contractor who develops the software, the validation effort is performed by personnel who are independent of the actual development effort. This internal independence ensures that the inherent risks of having the developer verify their own code are avoided.

5.2.5 Performance Verification Testing

This higher level of testing is required when called for by the approved verification plan. This testing will be required due to the complexity of the change, unique timing issues, regression test requirements, or the requirement to verify the interface with flight software and hardware at the SAIL or KATS.

Specific instances of this level of testing might be the regression testing required for a major release of CCMS System Software, or the requirement to verify a TCS program running in the SAIL redundant set GPC with JSC–provided Flight Software. Other drivers could include Ground Launch Sequencer (GLS) total set runs to verify timing remains correct after incorporation of a change in the GLS software. Also supported is the activity at SAIL to verify the KSC ground software to JSC flight software interfaces in support of JSC flight software development.

The level of verification plan will vary depending on the specific testing to be supported. Regression testing for system software is a part of the formal test plan. KSC support at SAIL of JSC flight software development would be documented on a SAIL Test Preparation Sheet (TPS).

Embedded V&V Activity: This activity accomplishes the verification of interfaces, the verification that there have not been impacts to unchanged software because of the implemented changes, and the status of critical timing issues where changes might have caused impacts. This activity ensures that the changes implemented have not

affected existing code much like the functional verification testing ensures that the actual change was correctly implemented.

5.2.6 PRACA Analysis

PRACA documents (IPRs, PRs, DRs) are problems or anomalies discovered in the operational Ground Software (GSW) or identified in the approved requirements design. PRACA documents are generated throughout the software life cycle by the various members of the GSW community involved in development, verification, or hardware testing. The PRACA system provides a continuous check and balance on the performance of the software and its capability to meet approved requirements.

Embedded V&V Activity: Problem reporting is a V&V activity performed by the continuous utilization, evaluation, and review of GSW operations by the technical community. The GSW evaluation PRACA paper is subject to detailed systems engineering analysis to determine their criticality and validity. The GSW community software engineers evaluate the range of options available to correct the discrepancy and prepare the necessary disposition recommendations for action by the appropriate board (see Figure D–3).

5.2.7 Configuration Closure

As addressed in Paragraph 5.1, requirements are generated by the various design centers which impact ground software. These requirements are processed, assessed, impacted and when approved by the local control board become the implementation authority for a ground software change.

The final portion of the ground software verification process involves the final configuration baselining of the software and the closure of the driving requirement.

Configuration baseline verification is performed as a portion of verification activity. This will include program revision–to–revision compares and code listing reviews to ensure that only the authorized changes were made. The revision–to–revision compare will not be performed in cases of major program rewrite or for new programs.

Configuration accounting is performed when the new software revisions are placed under formal control and the authorizing work items in the applicable software development contractors tracking system is closed. The verified revision and the driving change are tied together.

Closed–loop accounting, when required, is performed to provide formal feedback to the design center that all work related to the specific change has been completed and the design center effectivity/constraint has been addressed and functionally met.

Embedded V&V Activity: The tracking and closure of ground software development activity ensures that all required activity for a given milestone is accomplished. The closed–loop reporting ensures the design center, as well as all intermediate approval authorities are aware of the configuration of the products for which they are responsible. This configuration accounting activity is the last check and balance activity prior to the programs utilization with hardware.

5.3 GROUND SOFTWARE MISSION FLOW PREPARATION

While this activity is not actually ground software development, it is felt that this document should contain a summary of how the various ground software products are assembled into a package which is configured to perform the required hardware testing. These packages will support activities such as payload processing, complex control center support, and vehicle flow processing and launch (see Figure D–4).

5.3.1 CCMS Data Bank Development

The CCMS Data Bank is a mandatory portion of the ground software package. The CCMS Data Bank is a large data base which contains all measurement and command descriptive data attributes for hardware and software that is controlled or monitored by the CCMS.

This data includes a unique name for each measurement and command, its general description, and specific engineering data such as engineering units and range, hardware addressing, data paths and format information.

The data in the CCMS Data Bank is derived from engineering data supplied by the various design centers. Vehicle and payload engineering is provided by JSC in the form of DCRs and Shuttle Software Change Requests (SSCRs). Total vehicle and payload data is provided in mission–unique data tapes provided by JSC. GSE engineering is provided by the design center responsible for the GSE. For example, this could be KSC design for pad GSE or possibly a payload contractor for a piece of payload unique GSE.

The CCMS Data Bank is under CM control. Change implementation authority follows the process outlined in Paragraph 5.1.

The Data Bank is partitioned by USERID to preclude unauthorized modifications to one discipline's data by another discipline. Each command or measurement, called a Function Designator (FD), is made up of a compiler record containing descriptive data such as nomenclature, and a series of hardware records which contain hardware specific data such as measurement range and address (data path) data. The number of hardware records depends on the number of configurations the FD is required to support. A specific subset of the total data bank will reflect the configuration for a specific flow or hardware configuration.

Embedded V&V Activity: The formal controls on the CCMS Data Bank ensure that the defined ground software package contains only valid measurements and commands and their related engineering description and data paths. The quality controls on the CCMS Data Bank development and sustaining engineering process ensure that it accurately reflects design center engineering.

5.3.2 Ground Software Package Development

The Ground Software Package, called a TCID, is the package which is assembled on SDC and loaded in the CCMS set. The TCID is a collection of application programs and CCMS Data Bank data which specifically is designed to support a test, series of tests, or perform specific monitor and control functions.

The TCID development process exercises controlled utilities and includes extraction of a subset of the CCMS Data Bank which defines the hardware with which the TCID will communicate. The process also develops a series of tables, based on data bank contents, which will be loaded in the various CCMS components to establish the required communication path within the CCMS set.

Again, based on the planned utilization of the TCID, a subset of the application programs residing in the Application Program Library (APL) are added to the TCID.

The completed TCID will contain all application programs with measurement and command data including data path resolution required to support a specific hardware configuration or test activity.

Embedded V&V Activity: The development of a TCID to support hardware testing is a controlled process. All requirements are approved as outlined in Paragraph 5.1. The TCID is a collection of approved and verified application software and data bank information. This controlled activity ensures that the testing supported by the TCID utilizes a known baseline consisting of approved engineering. An additional, and significant, activity is the automatic identification of TCID build errors which are generated by the TCID Build software. These errors identify such errors as missing FDs, missing called or calling programs, invalid passed parameter, or if the data bank has changed since the program was compiled and the change would impact the integrity of the compile. All errors must be documented and dispositioned prior to TCID release to hardware support.

5.3.3 Ground Software Package Release To Hardware Support

The completed TCID is formally released to the CCMS set operation group. This release is the final step in developing and presenting to the test team the implementation of the approved changes for a given hardware configuration. The release process

also includes the specification for the compatible release of the CCMS System Software which is required to establish the operating environment to support the configuration of the TCID.

Prior to this point, the CCMS System Software has also undergone a formal release process much like the TCID or Application Software. Once this software has been verified, it is placed under formal control in its software library as released software. At this point, it becomes available for utilization.

Embedded V&V Activity: The release of the TCID and CCMS System Software are the final steps in delivering these configuration managed products to the test team. Each separate component of the total package is assembled into the CCMS software package specifically designed to support the designated activity. The procedural controls on this build process ensure that the integrity of each component is carried to the end product.

5.3.4 Ground Software Package Control Room Loading

The released TCID is provided on tape and the released CCMS System Software is provided on disk to the control room operations group. The CCMS operations group, based on published schedules, combines these two released products into one disk which is utilized to load the CCMS set. Their process is controlled by published maintenance manuals and documented on TPSs to form a historical trail of the CCMS control room loading operation. Once the loading is complete, the TCID and its associated programs, System Software, and related data is ready to support scheduled hardware activities, including launch. For CCS TCIDs, a System Integration Test (SIT) must also be successfully performed before the software is considered ready for support.

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FIGURE D–1

KSC GROUND SOFTWARE REQUIREMENTS DEFINITION PROCESS

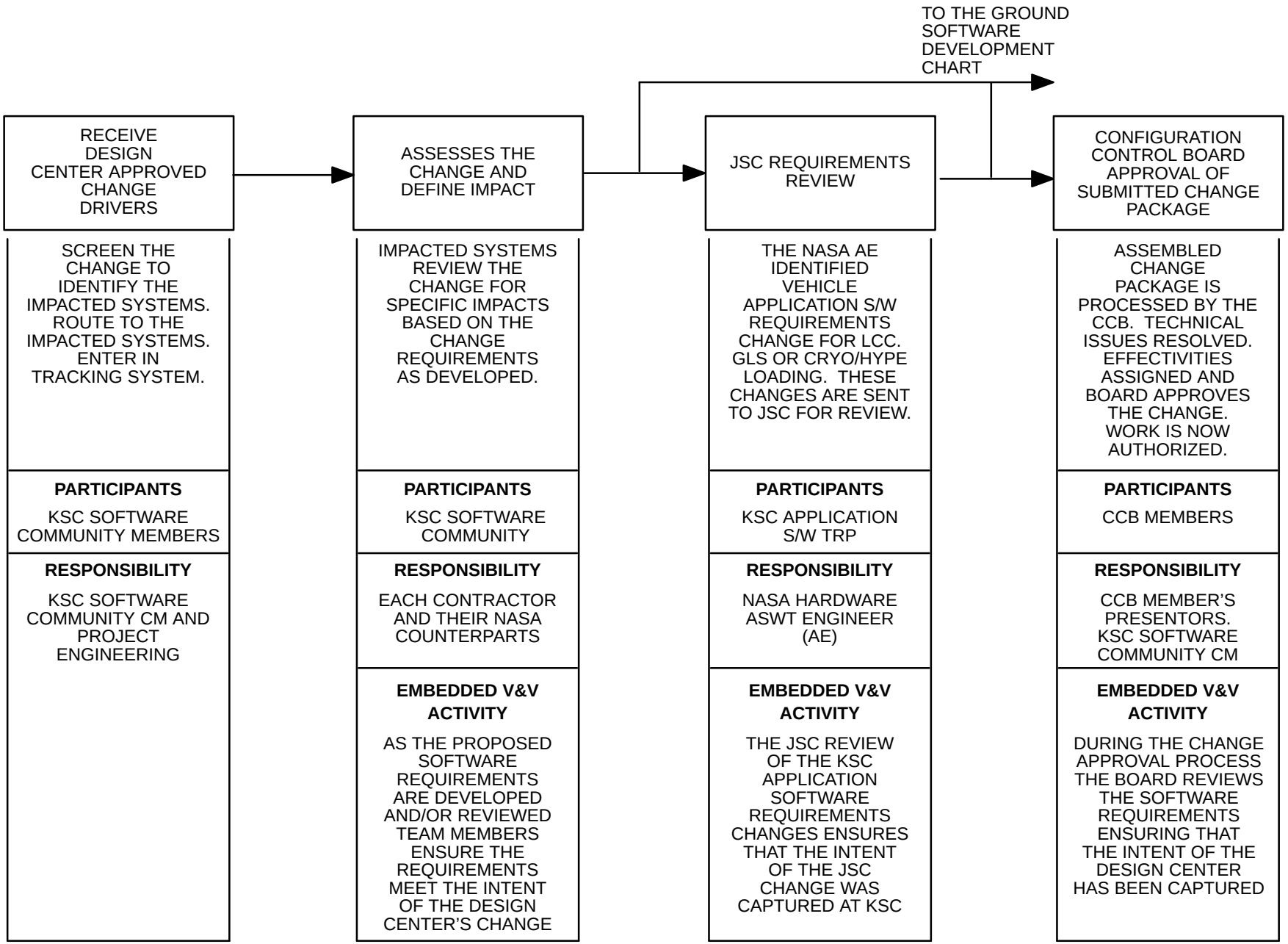
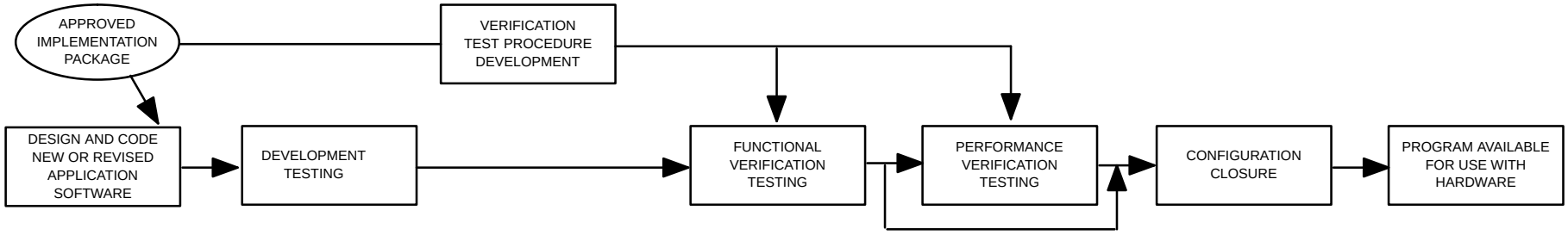


FIGURE D–2

KSC GROUND SOFTWARE DEVELOPMENT PROCESS



UTILIZING APPROVED SOFTWARE REQUIREMENTS DEVELOP CODE CHANGES OR NEW PROGRAMS TO MEET THE REQUIREMENTS UPDATE AS–BUILD SPECIFICATIONS AND USER GUIDES.	PERFORM AN INTERNAL TEST OF THE NEW OR REVISED SOFTWARE DECLARE THE SOFTWARE READY FOR VERIFICATION (100% DEBUGED).	DEVELOP FORMAL VERIFICATION/ VALIDATION PLANS/PROCEDURES BASED ON APPROVED REQUIREMENTS.	TESTING PER-FORMED TO VERIFY THE IMPLEMENTED CHANGE FUNCTIONS AS THE SOFTWARE REQUIREMENTS DIRECTED THE INDEPENDENTLY DEVELOPED PLAN DIRECTS THIS EFFORT.	WHEN REQUIRED BY THE APPROVED VERIFICATION PLAN THIS LEVEL OF TESTING WILL BE REQUIRED DUE TO SUCH CHANGES AS TIMING, INTERFACES WITH FLIGHT SOFTWARE, ETC.	THIS INVOLVES THE CLOSURE OF THE CHANGE PACKAGE REFLECTING COMPLETION OF THE CHANGES DRIVEN BY THE APPROVED REQUIREMENTS. IT ALSO INCLUDES A CONFIGURATION AUDIT TO CONFIRM ONLY INTENDED CHANGES WERE MADE. WHEN REQUIRED BY LVII CLOSED LOOP REPORTING IS PERFORMED.
PARTICIPANTS KSC GROUND SOFTWARE CONTRACTOR (SPC, BOC, PGOC)	**PARTICIPANTS** KSC GROUND SOFTWARE CONTRACTOR	**PARTICIPANTS** KSC GROUND SOFTWARE CONTRACTOR NASA COUNTERPART	**PARTICIPANTS** KSC GROUND SOFTWARE CONTRACTOR NASA COUNTERPART	**PARTICIPANTS** KSC GROUND SOFTWARE CONTRACTOR NASA COUNTERPART	**PARTICIPANTS** KSC GROUND SOFTWARE CONTRACTOR NASA COUNTERPART
RESPONSIBILITY KSC GROUND SOFTWARE CONTRACTOR	**RESPONSIBILITY** KSC GROUND SOFTWARE CONTRACTOR NASA COUNTERPART	**RESPONSIBILITY** KSC GROUND SOFTWARE CONTRACTOR (ENGINEERS OTHER THAN THE S/W DEVELOPER)	**RESPONSIBILITY** KSC GROUND SOFTWARE CONTRACTOR (NON–SOFTWARE DEVELOPER)	**RESPONSIBILITY** KSC GROUND SOFTWARE CONTRACTOR (NON–SOFTWARE DEVELOPER)	**RESPONSIBILITY** KSC GROUND SOFTWARE CONTRACTOR (QUALITY AND/OR CONFIGRUATION MANAGEMENT)
EMBEDDED V&V ACTIVITY PEERS REVIEWS ENSURE COM-PLIANCE WITH CODING STANDARDS AND ONLY APPROVED CHANGES ARE INCORPORATED.	**EMBEDDED V&V ACTIVITY** FINAL REVIEW BY THE DEVELOPMENT COMMUNITY THAT THE REVISED S/W FUNCTIONS AS INTENDED.	**EMBEDDED V&V ACTIVITY** PLAN DEVELOPED INDEPENDENTLY OF THE SOFTWARE CONTROLS AND DIRECTS THE VERIFICATION EFFORT. THE PLAN BECOMES A MAJOR PART OF THE AUDIT TRAIL OF VERIFICATION.	**EMBEDDED V&V ACTIVITY** THIS IS THE FORMAL VERIFICATION THAT THE NEW/REVISED CODE FUNCTIONS AS INTENDED. THE APPROVED TEST PLANS BECOME THE DOCUMENTATION OF THE ACTUAL PERFORMANCE.	**EMBEDDED V&V ACTIVITY** THIS ACTIVITY ENSURES THAT THE RELATIONSHIP WITH OTHER FUNCTIONS HAVE NOT BEEN IMPACTED BY THE INCORPORATED CHANGE. THE FINAL VERIFICATION THAT THE PROGRAM PERFORMS AS INTENDED.	**EMBEDDED V&V ACTIVITY** THIS ENSURES THAT REQUIRED DEVELOPMENT ACTIVITIES FOR A GIVEN MILESTONE HAVE BEEN ACCOMPLISHED AND THAT ONLY AUTHORIZED WORK WAS PERFORMED. CLOSED LOOP REPORTING PROVIDES FEEDBACK TO THE DESIGN CENTER.

FIGURE D–3

PROBLEM REPOSTING AND CORRECTIVE ACTION ANALYSIS

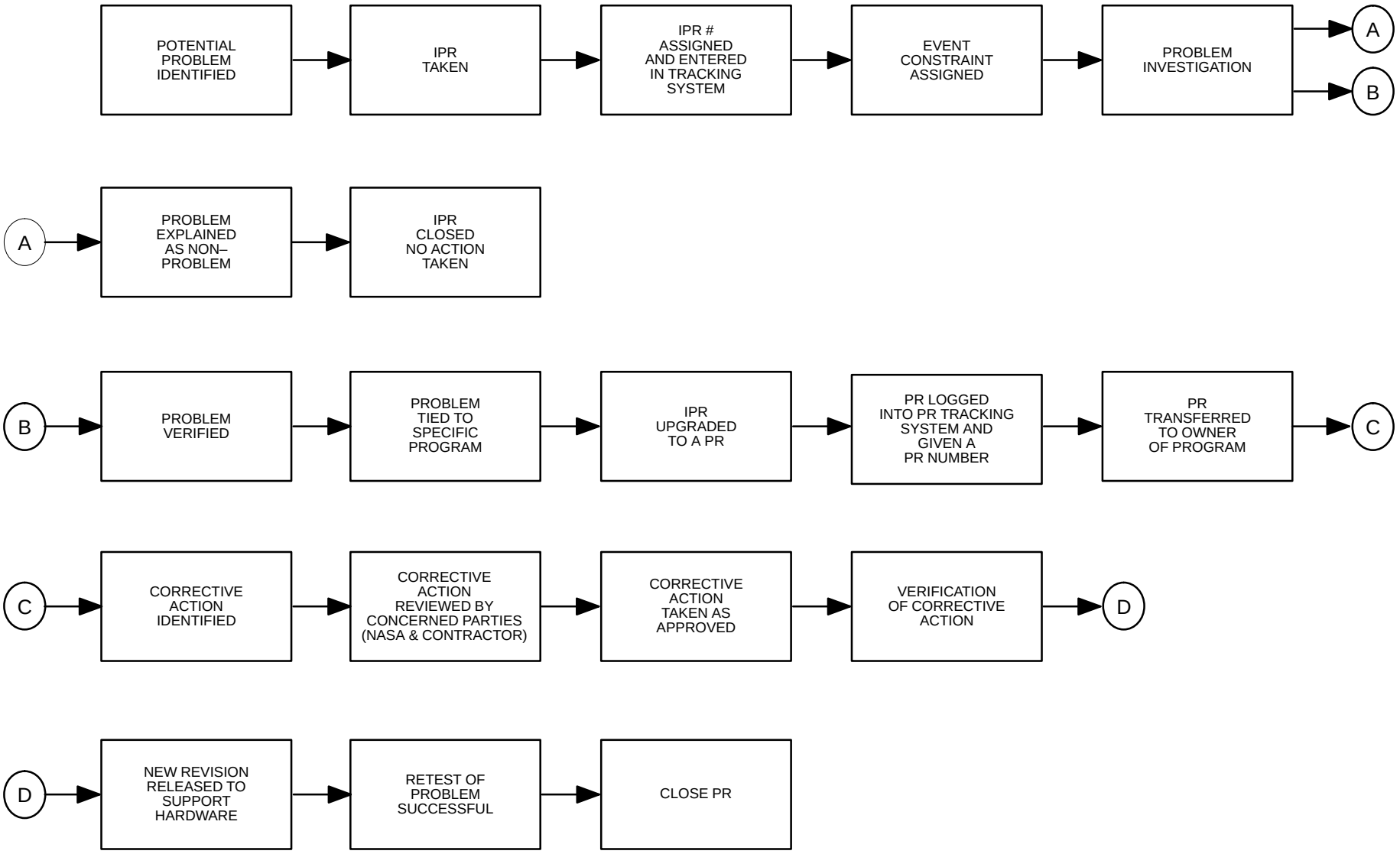
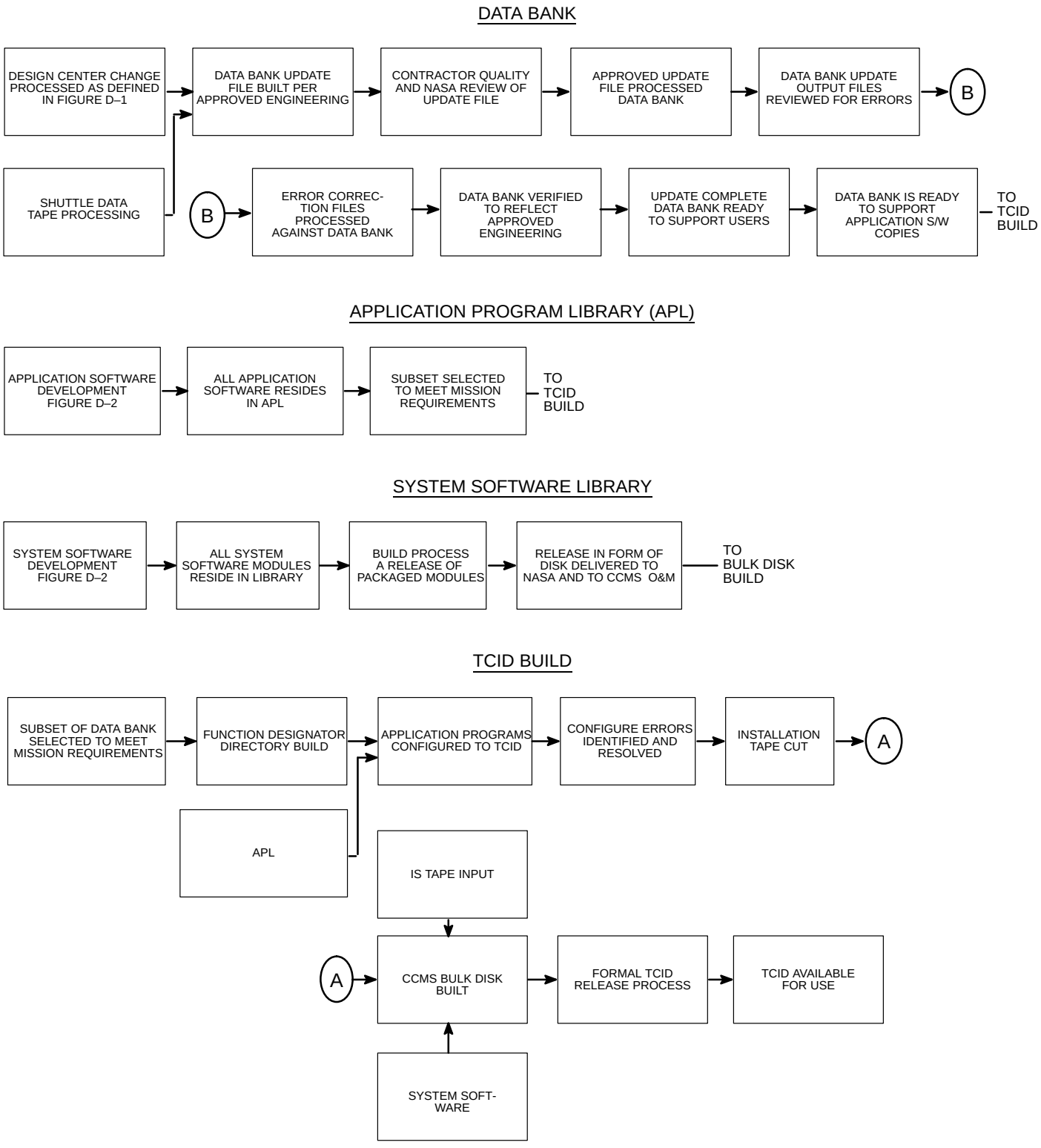


FIGURE D–4

KSC GROUND SOFTWARE MISSION FLOW PREPARATION



APPENDIX E

JSC/CONSOLIDATED CONTROL CENTER
SPACE SHUTTLE PROGRAM
GROUND SYSTEMS SOFTWARE
EMBEDDED VERIFICATION AND VALIDATION REQUIREMENTS

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APPENDIX E

JSC/CONSOLIDATED CONTROL CENTER
SPACE SHUTTLE PROGRAM
GROUND SYSTEMS SOFTWARE
EMBEDDED VERIFICATION AND VALIDATION REQUIREMENTS

1.0 PURPOSE

This document defines and establishes the SSP baseline requirements for the developmental and sustaining engineering contractor's integrated verification and testing process and establishes the activities and responsible program elements in this process for Ground Systems Software (GSSW). GSSW consists of Mission Operations Computer (MOC) software, workstation applications, Digital Voice Intercommunications System (DVIS), Telemetry Preprocessor Computers (TPC), and Meteorological Interactive Data Display System (MIDDS).

2.0 APPLICABLE REFERENCES

N–TX–035/000/03	CCC MOC Software and Integration Department Operating Plan, with all annexes.
NASA–JSC–23474	Change Certification Policy for CCC Critical Software Processors, and all appendices.
No Number	Paramax CCC Software and Integration Depart–ment Standard Operating Procedure 90–002.

3.0 INTRODUCTION

The SSP GSSW technical community defines, develops, and uses the SSP GSSW. Prime members of the community are NASA's MOD and the STS contractors. The prime contractor is Rockwell Space Operations Company (RSOC). The Development and Sustaining Engineering (D&SE) contractor is Paramax Systems Corporation. The operational contractor is AlliedSignal Technical Services Corporation (ATSC). In general, the primary responsibilities of these organizations are as follows:

MOD: Generation of Support Requirements (SRs) and usage of end product for mission support.

prime: Generation of SRs and usage of end product for mission support.

D&SE: Generation of SRs, development of new software, maintenance and modification of existing software, testing, validation and verification, and release of new/modified software and reconfiguration products.

operational: Generation of SRs, assist in testing of new/modified software, the operational end user of products generated by the prime and D&SE contractors.

4.0 SPACE SHUTTLE PROGRAM GROUND SYSTEMS SOFTWARE TECHNICAL COMMUNITY

The SSP GSSW technical community is comprised of NASA's MOD and the companies under the SOC. SOC members are under contract to NASA for sustaining engineering of the CCC hardware and software components.

Each member of the GSSW technical community has the same objectives, goals, and perspectives with respect to the actual development and operational utilization of the GSSW. Members of the community support development, test, and operations in several facilities. The various viewpoints and operations of the community provide an effective V&V function throughout the GSSW's life cycles.

4.1 NASA – MISSION OPERATIONS DIRECTORATE

MOD will develop the operational requirements for all components of a Shuttle mission. MOD is composed of independent divisions of multiple branches. The flight planning process involves a top–down–bottom–up structured approach to mission planning. MOD will break down top–level objectives into specific objectives for MOD divisions and/or branches who will develop plans within their area of responsibility to attain these objectives. Each division and/or branch will then integrate lower–level plans into the final mission plan and objectively test them prior to management review and approval. MOD will use the SMS complex at JSC for validation of mission plans and procedures in conjunction with the Shuttle Data Processing Complex (SDPC) MOC at JSC.

Embedded V&V Role: Once MOD approves the mission plan, MOD organizations and/or their support contractors will review and update mission requirements documentation as required to accomplish the mission objectives stated in the areas of communications, mechanical systems, remote manipulator system, electrical and environmental systems, flight design, flight dynamics, navigation (ascent/orbital/entry), ground support, reconfiguration, and mission training. MOD will validate changes during MOD flight simulations using the SMS and flight planning software tools. The evaluation and approval process within MOD performs an effective V&V role for developing and verifying the GSSW requirements.

4.2 SOC QUALITY ASSURANCE/QA

The SOC QA Program is designed to assure that the SOC organizations perform in accordance with approved standards, procedures, and processes for the deliverable products of the Ground Systems.

4.3 GROUND SYSTEMS SOFTWARE SUSTAINING CONTRACTORS

The primary concern of the three SOC contractors will be the implementation of software modules and their operation in Ground Systems computers. Each contractor will use functionally independent organizations to analyze SRs, design and code GSSW changes, manage GSSW configuration, build different GSSW versions (“loads”), and verify that changes are correctly implemented. The sustaining contractors will perform rigorous reviews throughout the GSSW definition, implementation, and verification phases. These review processes must cover requirements, design, code, test procedures, and test results. They are designed to eliminate errors early in the software life cycle.

SOC will be responsible for all reconfigurable mission loads from the OI base delivered from the FSW development contractor. SOC personnel will integrate loads with FSW data, flight initialization data, telemetry format data, and GSSW updates, to prepare an integrated Flight System for the Ground Systems computers. SOC personnel will then perform a mission–specific series of tests to verify the final integrated system performance.

Embedded V&V Role: The sustaining contractors will maintain functionally independent organizations that review and examine the GSSW at each stage of development. The requirements group review must ensure that the specified requirements are understood and that the GSSW module designs incorporate the intent of these requirements. The programming group must ensure that the GSSW module designs are coded properly according to approved development standards. The D&SE contractor’s Integrated Verification and Test (IV&T) group must then verify that the code executes properly and accomplishes the functions stated in the requirements. The Load Build group will ensure that only approved GSSW modules are used in loads released for final delivery.

5.0 CONSOLIDATED CONTROL CENTER

The CCC is comprised of several related subsystems that operate with SOC developed and maintained GSSW. Examples of these systems are:

a. CCC Front End Processing System (FEPS). This system is comprised of many hardware and software components, the primary function of which is to process all telemetry data received by JSC CCC. IV&T will reconfigure the TPCs with flight–specific data received from the D&SE Reconfiguration Department.

b. Meteorological Interactive Data Display System (MIDDS). The main purpose of MIDDS is to acquire, store, analyze and integrate a wide variety of atmospheric data, thus making graphic and alphanumeric displays accessible to meteorologists to aid in forecast preparations for Shuttle missions and simulations. MIDDS is supported and maintained by the D&SE contractor.

c. Digital Voice Intercommunications System (DVIS). The main purpose of the DVIS system is to provide a flexible communications interface system that may be reconfigured in realtime to meet users' changing needs. Since it is a digital system, it has its own software system and independent computer for greater flexibility than its predecessor.

d. Workstations (W/S). Workstations are provided to CCC users for additional computing power and specialty applications. A W/S derives its software from configuration–managed files maintained by the IV&T group on the Flight Support Host (FSH), which are downloaded by users as required. Once the files are downloaded, the W/S functions independently. It communicates via Local Area Networks (LANs) with the FSH and the Realtime Host (RTH) to retrieve data to perform its functions.

e. Mission Operations Computer (MOC). The MOC flight load is comprised of the output of the reconfiguration system, the current version of software, and the current version of host operation system. The primary function of the MOC is to provide a realtime processing capability for controllers to perform the command and control of the Shuttle.

   Users (customers) at work in the Flight Control Rooms (FCRs) and Multipurpose Support Rooms (MPSRs) can invoke appropriate displays on the consoles as needed. The FCRs and MPSRs contain data entry services, Manual Entry Devices (MEDs), and Push–Button Indicators (PBIs), which allows users to request data displays and issue commands that are processed by the MOC and uplinked to the Shuttle. The MOC also processes radar data, calculates state vectors, and provides network communications status data, and provides mission planning processing of Command functions.

   Users perform a number of functions on the FSH. Among these are CM for W/S, Near Realtime Telemetry (NRT) processing and software development.

6.0 GROUND SYSTEMS SOFTWARE MODIFICATIONS

Software modifications, flight data base modifications, etc., must begin with an expressed need defined by the GSSW community. These needs are identified in flight or mission plans, ground system or equipment modifications, SRs, DRs, etc.

6.1 NEEDS ANALYSIS

Once the community defines a need, SOC must perform analyses to determine the implication for the GSSW. The Software Sustaining Engineering (SSE) personnel within the D&SE contractor will perform these analyses. The end result will provide a basis upon which SOC can determine a direction for implementation.

The prime contractor will perform configuration control coordination between NASA and SOC. The Software Technical Services department of the D&SE contractor will perform coordination between the prime and D&SE contractors. As a result, all change traffic to and from the D&SE contractor's CCC Software and Integration department must pass through the Software Technical Services department.

Once NASA approves a defined need for implementation, the D&SE contractor's programmers will update the appropriate Level B and C Requirements document to reflect the change, if required.

Embedded V&V Activity: The GSSW community members will perform the system engineering analyses, accomplishing V&V. Other members of the community will subject the formulated needs to systems engineering analysis in order to validate requirements. Once the knowledgeable GSSW community personnel determine a valid GSSW requirement exists, an originator will prepare the necessary SR documentation.

6.2 DISCREPANCY REPORTS

DRs are a tool to document anomalies discovered in the operational GSSW. DRs are generated throughout the GSSW life cycle by the various members of the GSSW community involved in the development, maintenance, verification, testing, and operations (e.g., developers, testers, flight controllers, etc.).

DRs are analyzed by community members to determine the appropriate disposition (i.e., "Correct Code", "Waive", "Issue Operational Note", "User Error", "Invalid DR", etc.). This analysis includes a determination of a need for a software change. If the analysis indicates a need for a requirement change, the DR disposition will be that an SR be submitted by the GSSW community for consideration. Otherwise, if a code correction is required, the appropriate GSSW development/maintenance group will provide the necessary implementation plan for the correction.

Embedded V&V Activity: The technical community will perform V&V by reporting discrepancies through the continuous utilization, evaluation, and review of the operational GSSW. They will subject the DRs found to detailed systems engineering analyses to determine their criticality and validity. The GSSW community engineers will then evaluate the range of options available to correct the discrepancies and prepare the necessary disposition recommendations for action.

6.3 SUPPORT REQUIREMENTS

SRs are the tools used to document new requirements assigned to the GSSW. A community member will generate an SR to identify a new requirement and will pass it to a screening board in the integrator's company, who will evaluate its merit. If approved for implementation, the SR will then proceed to the responsible D&SE contractor departments, who will each estimate the amount of resources they will need to complete the requirement. The departments will then submit the estimations to the approval board, which will issue a Technical Direction Letter (TDL). Upon receipt of the TDL, the D&SE department will assign the SR to the respective section for review and design implementation, and then to IV&T for formal testing, acceptance, and update to Flight Systems and future software versions for mission support.

Embedded V&V Activity: The embedded V&V activity is through the involvement of all organizations in the GSSW community. They must effectively validate the interface compatibility and appropriate interactions between all the affected functions. As a team, they must verify that the requirements are correct and complete, assuring that the intent is uniformly understood throughout the GSSW community.

7.0 GROUND SYSTEMS SOFTWARE DEVELOPMENT PROCEDURES

For SOC, the D&SE contractor's responsibility focuses primarily on providing the software engineering support necessary to maintain and modify existing software. Incoming DRs and SRs will outline the requirements for maintenance and modifications. See Figure E–1 for simplified and detailed block diagrams of the SR/DR Software Change Lifeline.

The software life cycle is a standard process for defining, creating, and implementing new software versions. The life cycle is a process for logically arriving at management and technical decisions regardless of the software purpose, size, or complexity.

The functional definition phase details the requirements of the SRs as defined by community members. This phase terminates after conducting a Preliminary Design Review (PDR), a meeting attended by the originator, MOD, and representative from the responsible D&SE department. The objective of the PDR is to review the results of the tasks performed and approve the functional definition of the new requirements. These will become the baseline referred to as the "Functional Baseline". It will be placed under configuration control. After completing the PDR, the responsible department will prepare design review minutes. The minutes identify the materials reviewed and problems uncovered, and specify the follow–up action items. Both the D&SE contractor and the users (customers) must approve the minutes.

7.1 DESIGN, CODE, AND UNIT/MODULE TEST

7.1.1

The design phase is devoted to creating the design solution for implementing the new functional requirement(s) or for correcting the reported discrepancies. This phase will terminate with a CDR. The D&SE application manager/supervisor conducts the CDR. The attendees include appropriate D&SE management representatives, version development team members, CM and QA representatives. The D&SE contractor should encourage customers to attend the review to monitor the technical progress of the version development.

The CDR is a technical review of new software. The CDR must establish the integrity of the detailed design prior to releasing it for coding and testing. The successful conclusion of the CDR will establish the design baseline and give authorization for release of the design to coding. After completing the CDR, the responsible department will generate the design review minutes. The minutes identify the material presented at the review, define problems uncovered, identify action items to resolve the problems, and designate the individual(s) responsible for resolving the problems. In the case where SRs and/or DRs are implemented on an individual basis, the PDR and CDR may be combined into a single review.

7.1.2

Code and Test phase includes the coding, integration and testing of the design. Software design testing will start as soon as coding of the first logically discrete unit is complete, and continue throughout the phase. The object is to validate the integrity of the code with respect to the design. This phase terminates when the application manager declares that the new software version is ready for IV&T.

7.1.3

D&SE programmers will conduct the Release and Test Requirements phase in parallel with the design and coding activities. The objectives of this phase are to plan and coordinate the contents of the new releases and to prepare the necessary documentation for the planning and execution of the qualification and acceptance testing.

CM personnel, in coordination with the development and test personnel, will plan the contents of the new version release. They will examine the department work plans to determine if a scheduled release impacts these plans. During the early stages of this phase, they will prepare a draft version of the VDD and present it at the CDR.

7.1.4

The objective of the Unit Test phase is to conduct a series of functional tests to verify that the programmers have satisfied the requirements of the functional baseline and

that the design solutions to the DRs resolve the reported problems. The programmers conduct these tests in accordance with the department–approved test plan and procedures. During this phase, they will divide the tests into two categories: qualification and acceptance tests.

Qualification testing will determine if the programmers properly installed the design/code, if the incorporated changes satisfy the function baseline requirements, and if the programmers have resolved any reported discrepancies. Additionally, D&SE programmers must perform tests to determine if system degradation has occurred as a result of the design. These tests are the final stage of the version design and development process. Programmers must correct design discrepancies uncovered during this phase of testing and then needs to retest it prior to initiating the acceptance testing.

The objective of acceptance testing is to demonstrate to the customers that the version development has been successfully completed. The acceptance testing is a selected subset of tests conducted during the qualification testing. Acceptance testing is complete when the software is declared operationally acceptable by the users (customers).

Embedded V&V Activity: Each activity has detailed written procedures which the D&SE contractor's software QA personnel must monitor for compliance. Preparation for each inspection will include a review of the procedures and standards utilized to accomplish a design, code a module, or perform a test. The attendees will complete and review detailed checklists prior to inspections required for code design and test reviews.

V&V is the responsibility of the D&SE contractor. The contractor accomplishes this by forming independent organizations responsible for tracking and verifying the approved requirement changes to the GSSW. Peer moderators will control all reviews and inspections without management involvement other than oversight review and approval of GSSW development standards and procedures.

The reviewers must inspect the design to ensure that it reflects both the stated requirements as well as the intended requirement. They must inspect the code to ensure conformity to GSSW standards, prevent unintended functions, and control inefficient CPU utilization and memory consumption. Design and code inspections can sometimes be combined for less complex changes. The reviewers must inspect tests to ensure they are performed at applicable levels of GSSW development (i.e., Unit and Module) prior to beginning GSSW integration via the load build process.

7.2 LOAD BUILD AND SYSTEM TEST

To prevent a constant state of software change, the D&SE contractor will schedule and package groups of changes for release. Each release is defined as a version; i.e., the actual configuration of a software package introduced at a given time for use or test.

The D&SE Load Build group will create a new version whenever the programmers prepare a newly developed software item for its first formal delivery or whenever the programmers modify existing software to incorporate approved SRs or correct DRs.

CCC software sustaining engineers will supply build inputs that reflect DRs and/or SRs to the software Load Build group. They will perform builds as required (generally once just prior to a reconfiguration data base release). The build process applies the authorized software modifications to the existing software system, creating a new version of the software.

Embedded V&V Activity: IV&T will receive this new software version for installation into the load. They will then verify the ability of the software to work with the flight–specific reconfiguration data base and the current operating system software by performing a Post–Build Test (PBT) and a four–day regression test.

7.3 VERIFICATION TEST PROCEDURE REVIEWS

Two levels of test reporting are required for all modifications applied to the software systems: standard test reporting and critical processor reporting.

7.3.1

The responsible tester will prepare standard test reports which are designed to test all features of the referenced Level B and C requirements, including a complete description of the components tested, a brief description of the modification or problem corrected, a description of the testing to be performed, and a summary of the test results. The tester will also include pretest reference information and test evidence documentation.

7.3.2

The MOD Assistant Director adds some software items to the Critical Processor List. IV&T will perform changes to critical processors as specified in JSC–23474 and in Paramax CCC Software and Integration Department Standard Operating Procedure 90–002. Critical processor test reporting includes all the requirements of standard testing with additional reports required contained on the Critical Processor Change Certification Form.

Embedded V&V Activity: The D&SE contractor's QA will review the standard test report, pretest reference information, test evidence documentation, critical processor test reports, and Critical Processor Change Certification Forms to ensure completeness of all testing processes and reports.

7.4 RECONFIGURATION INSPECTION

This embedded verification and validation activity will begin with the prebuild meeting that is held just prior to every software build. The purpose of this meeting is to authorize and ensure all items destined to be included in the build have been prepared by the programmers with valid DR and/or SR numbers and that all items for the build are accounted for and documented. After the build, the Load Build group will pass this build authorization data to IV&T, which will also verify the list of modifications and ultimately produce a Software Release Document (SRD) that represents the newly built software version.

8.0 GROUND SYSTEMS SOFTWARE MISSION PREPARATION

GSSW Mission preparation will begin with the Flight Planning Meeting that occurs at approximately L–150 days, about a week prior to Mission Automatic Reconfiguration System (MARS) Day 1 of the 140–day MARS Reconfiguration Template, outlined below.

MARS Day	Activities
1–26	Begin the Engineering Cycle (also called Cycle–1). The GSSW community customers (users) make input and process reconfiguration updates.
27–30	D&SE contractor Product Integration department delivers the reconfiguration products to the Load Build group for build of MOC data base products and software. They will then deliver the products to IV&T for installation.
31	Begin IV&T regression test, including PBT.
50	Integrated Interface Test (IIT).
55	Integrated Load Checkout (ILC).
60	Cycle–1 Release; begin Cycle–2, known as the Flight Cycle.
70	Ready for Integrated Testing (RFIT). Begin simulations and training.
84	Load Build group delivers Flight Cycle reconfiguration products to IV&T.
85–89	IV&T installation and PBT.
90	Cycle–2 Release.
up to L–30	DRs investigated and fixes installed and tested.

IV&T may apply changes and fixes identified as needed prior to the prelaunch freeze date, L–30 (with all required authorizations). After prelaunch freeze, only the most urgent fixes may be applied. In this case, the approval of the MOD management and the SOC Facility Project Manager is required.

8.1 RECONFIGURATION DATA

D&SE Reconfiguration Production will initially supply reconfiguration data to the Load Build group once for each Space Shuttle flight. They, in turn, combine this data, known as the Engineering Cycle (Cycle–1), with software flight independent products to produce a flight specific data base used with the software. SOC Reconfiguration Production supplies additional reconfiguration data to the Load Build group again for each Shuttle flight. This resupplying of a portion of the data is known as the Flight Cycle (Cycle–2) and is used to modify some values in the products to assure compatibility for the mission with the time of the year, the payloads, and the vehicle, etc.

Embedded V&V Activity: During the four–day regression tests, IV&T will verify the data base works with the software and the operating system software.

8.2 OPERATIONAL, VALIDATION AND CERTIFICATION TESTING

The Mission Operations Space Team (MOST) and MOD Flight Controllers will perform integrated operational testing. The Integrated Interface Test and Integrated Load Checkout (IIT and ILC) will use the resources of the SMS to emulate the actions of a Shuttle Vehicle and payloads for specific or generic flights to evaluate the performance of a complete flight system load. Subsequent testing will give training to all involved personnel as well as operational verification of the software for flight certification. These simulations will demonstrate the flight support readiness of the GSSW for given missions. The GSSW community must prepare and present reports and evaluations to MOD to report RFIT with the Simulation Readiness Review (SRR) and for flight with the FRR. Crew and mission operations training in the SMS exercise the man–in–the–loop GSSW interface to validate mission capability.

8.3 SIMULATION AND FLIGHT READINESS REVIEWS

SRR must occur prior to the start of integrated training. FRR must occur just prior to flight. The purpose of these reviews is to provide a certification statement of flight readiness and to address any open problems or issues.

Embedded V&V Activity: Each GSSW contractor and NASA organization having a role in preparation of GSSW for a flight is required to certify that preparations are completed and that to the best of their knowledge there are no known problems that affect the safety of the flight or completion of the STS mission.

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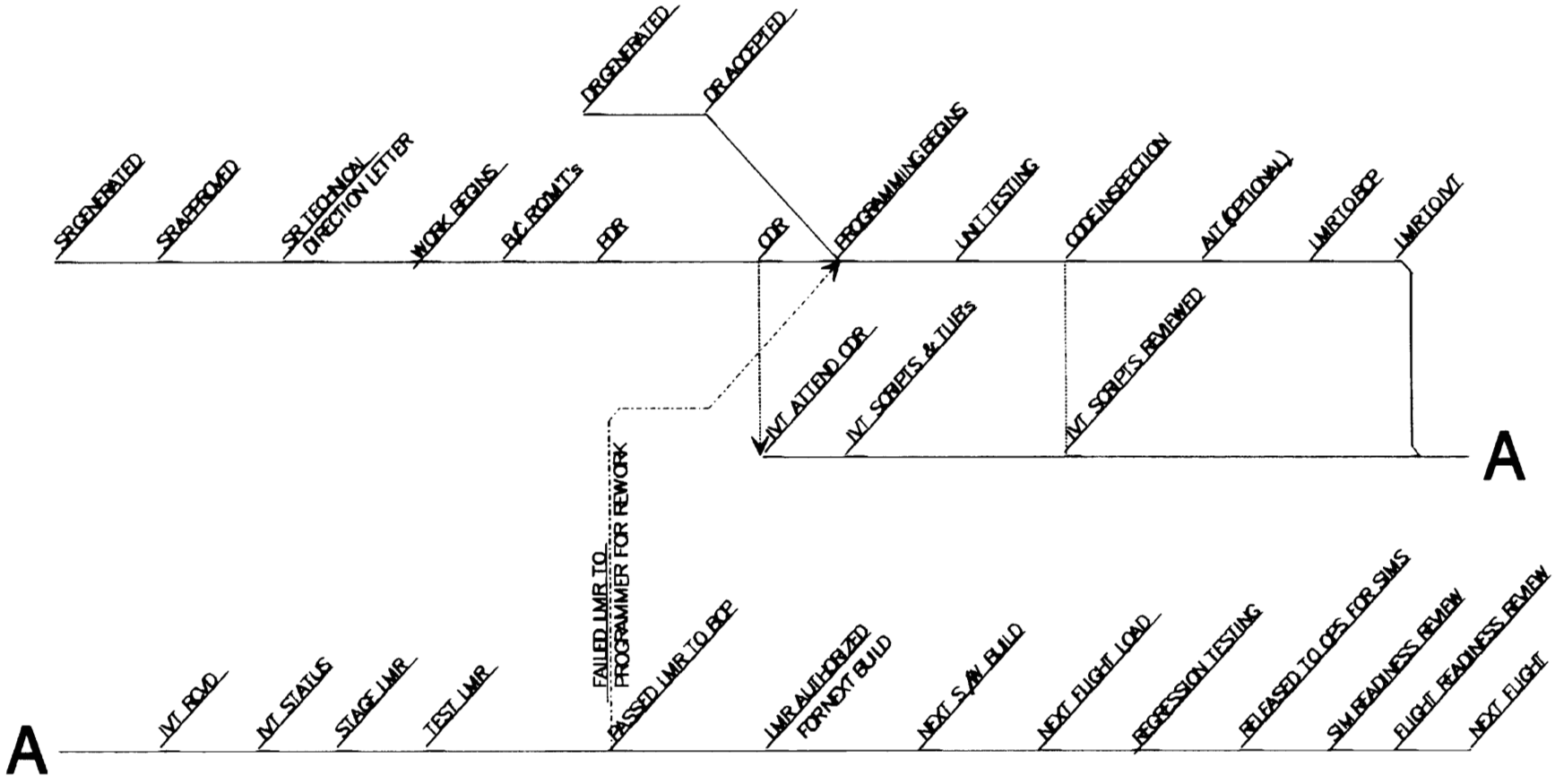
FIGURE E–1

SOFTWARE CHANGE LIFELINE

(Page 1 of 7)



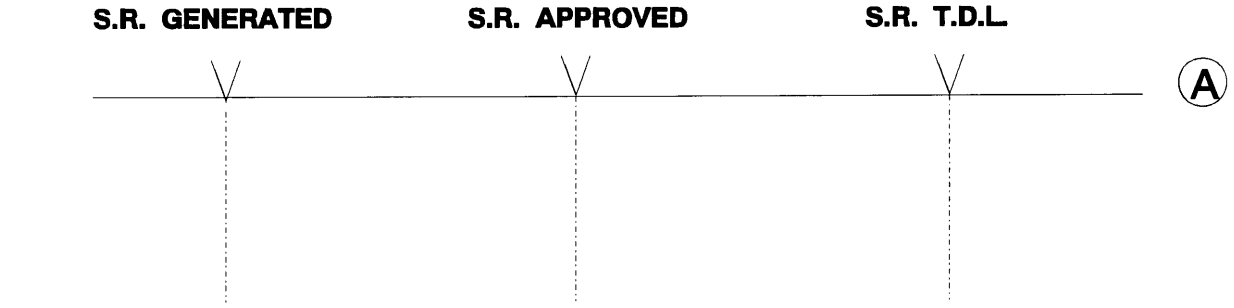
INTERVALS BETWEEN MILESTONES ARE FOR RELATIONSHIPS ONLY

AND ARE NOT MEANT TO REPRESENT SOME ACTUAL TIME FACTOR

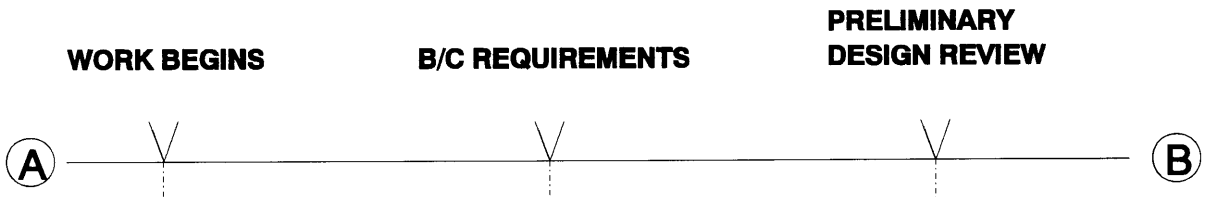
FIGURE E–1

SOFTWARE CHANGE LIFELINE

(Page 2 of 7)



PURPOSE	DEFINE NEW SOFTWARE REQUIREMENT	REVIEW AND AUTHORIZE S.R. FOR WORK	DIRECTS WORK TO BEGIN
RESPONSIBILITY	ORIGINATOR	STSOC / NASA	STSOC / NASA
PARTICIPANTS	PARAMAX: PGMRS; ORIGINATOR	NASA: MOD STSOC: RSOC	STSOC: RSOC; NASA: MOD
V & V ACTIVITY	S.R. ROUGH ORDER OF MAGNITUDE (EST. OF TIME/COST) COMMUNICATION W/ ORIGINATOR	S.R. APPROVED W/WO CHANGES; COST EFFECTIVE OR DESIREABLE; ASSIGN CHARGE ACCOUNT #.	AUTHORIZATION / DIRECTION TO BEGIN INPLEMENTATION OF S.R.



PROGRAMMER BEGINS WORK ON S.R. PARAMAX PARAMAX: PGMR COMMUNICATION W/ ORIGINATOR	SET FORTH THE SPECS NEEDED TO SATISFY THE INTENT OF THE S.R. NASA; STSOC ORIGINATOR; PARAMAX: PGMR COMMUNICATION W/ ORIGINATOR FOR ACCURACY / COMPLETENESS	REVIEW THE SPECIFICATIONS WITH ALL INTERESTED PARTIES NASA; STSOC ORIGINATOR; NASA: MOD PARAMAX: PGMRS, IV&T VERIFY/AGREE SPECS CORRECT/ MODIFIED

FIGURE E–1

SOFTWARE CHANGE LIFELINE

(Page 3 of 7)

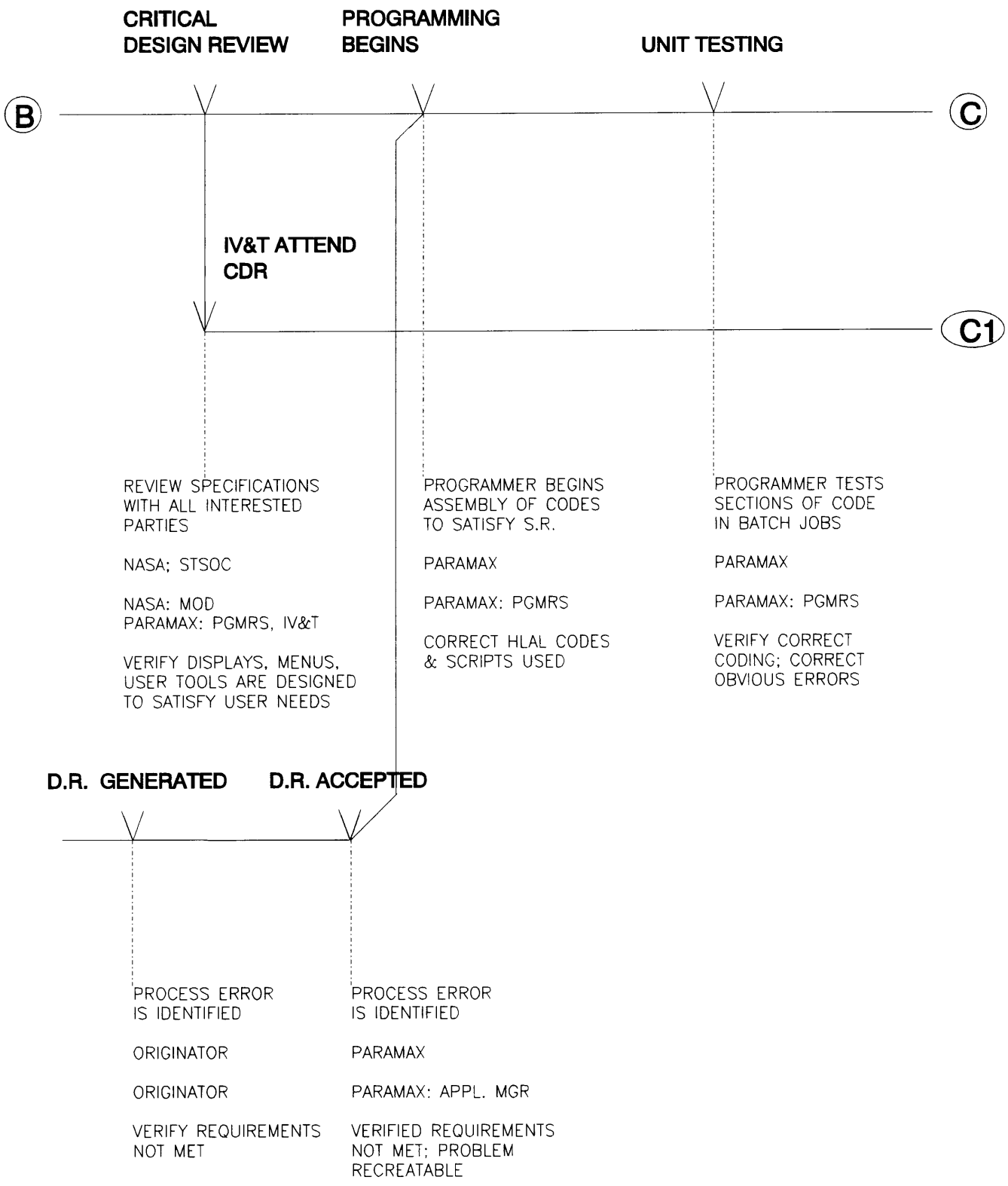


FIGURE E–1

SOFTWARE CHANGE LIFELINE

(Page 4 of 7)

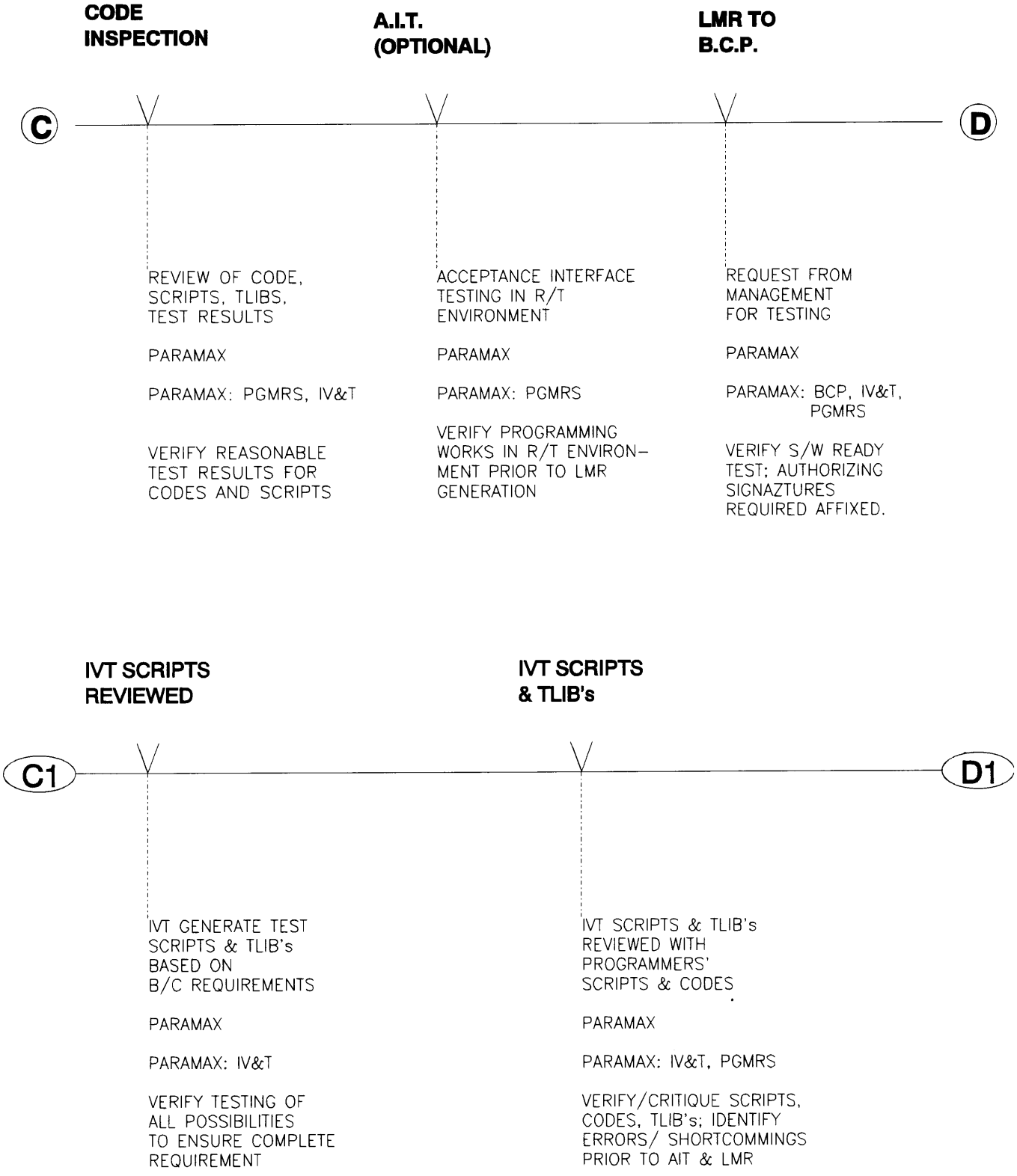


FIGURE E–1

SOFTWARE CHANGE LIFELINE

(Page 5 of 7)

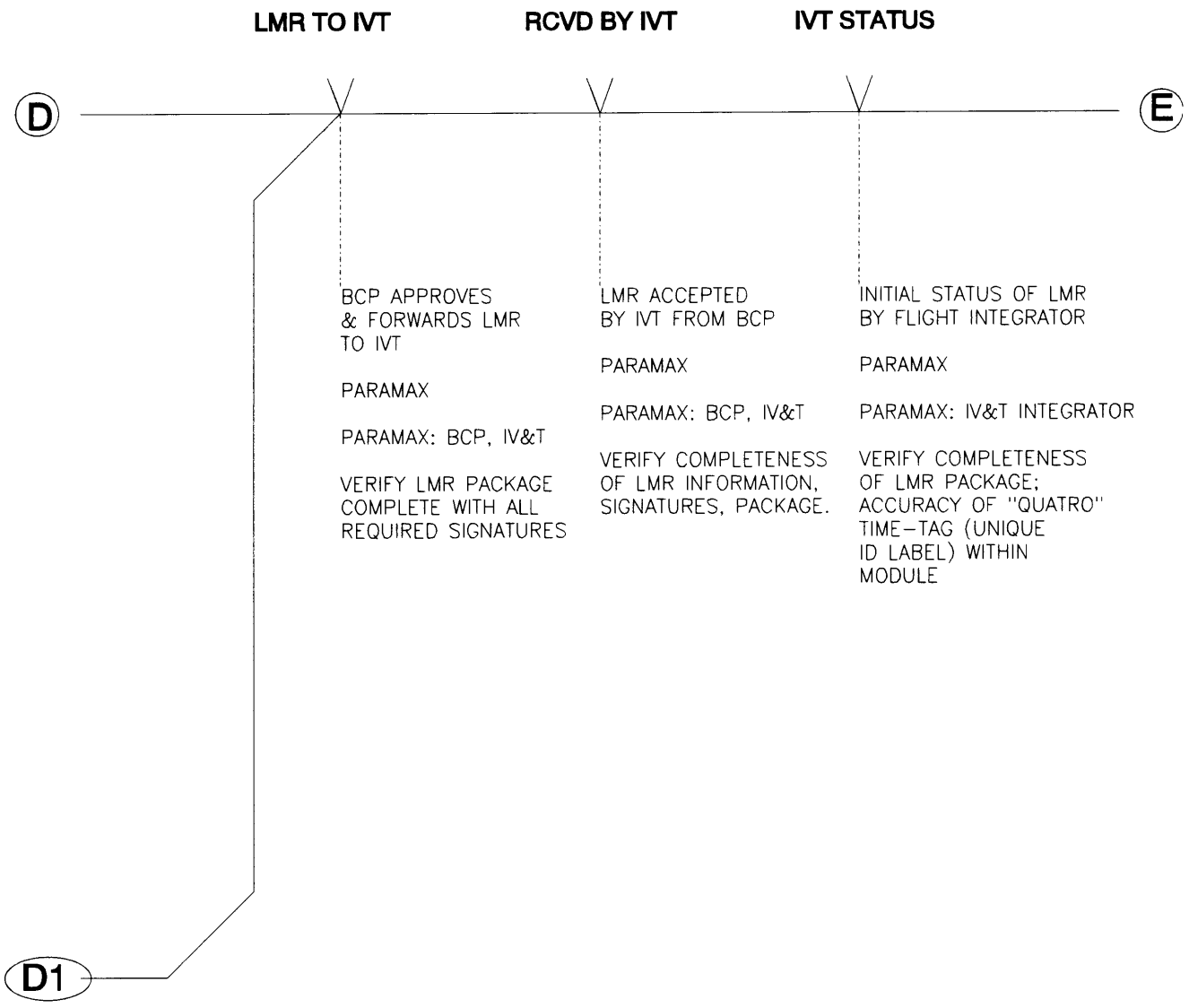


FIGURE E–1

SOFTWARE CHANGE LIFELINE

(Page 6 of 7)

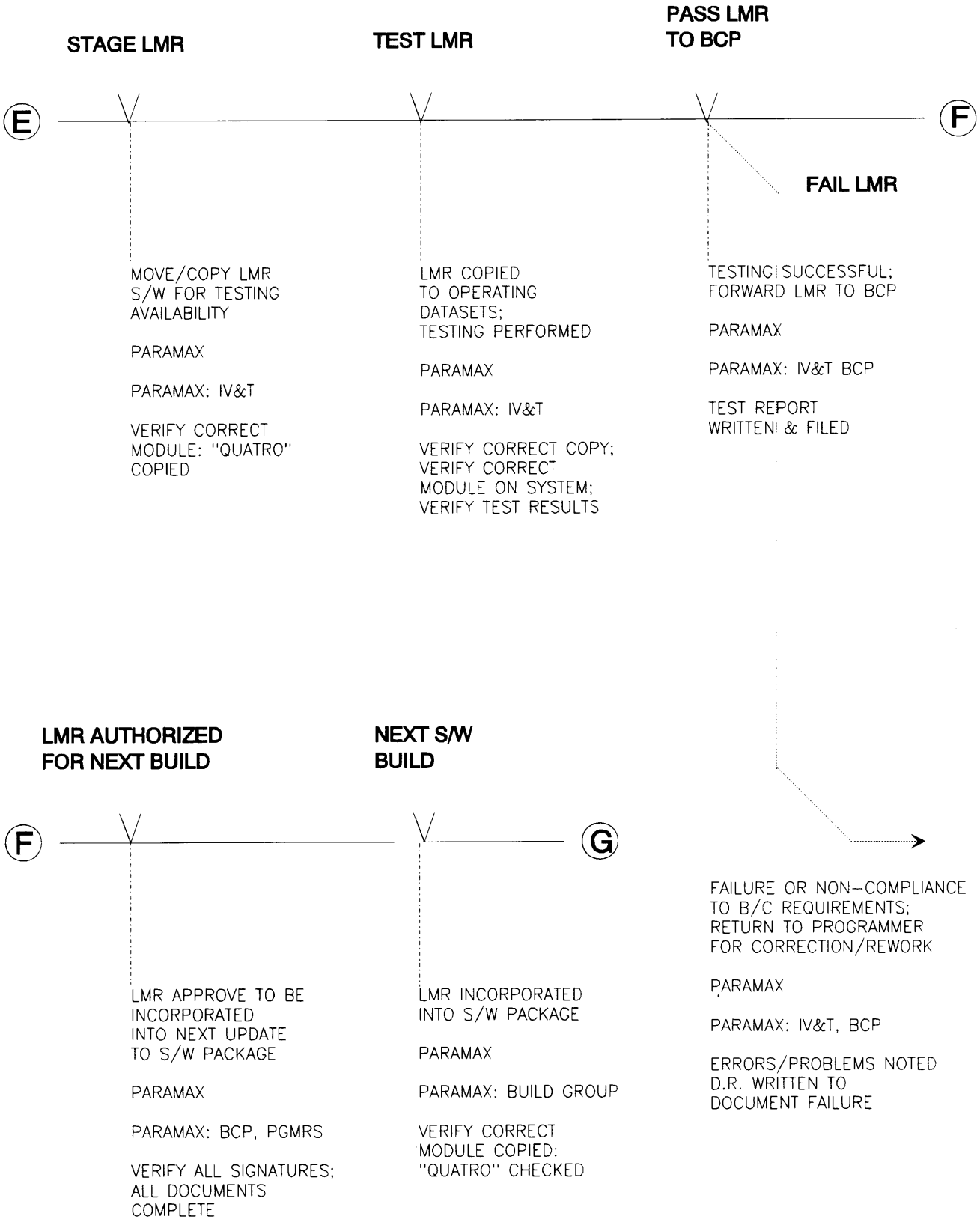
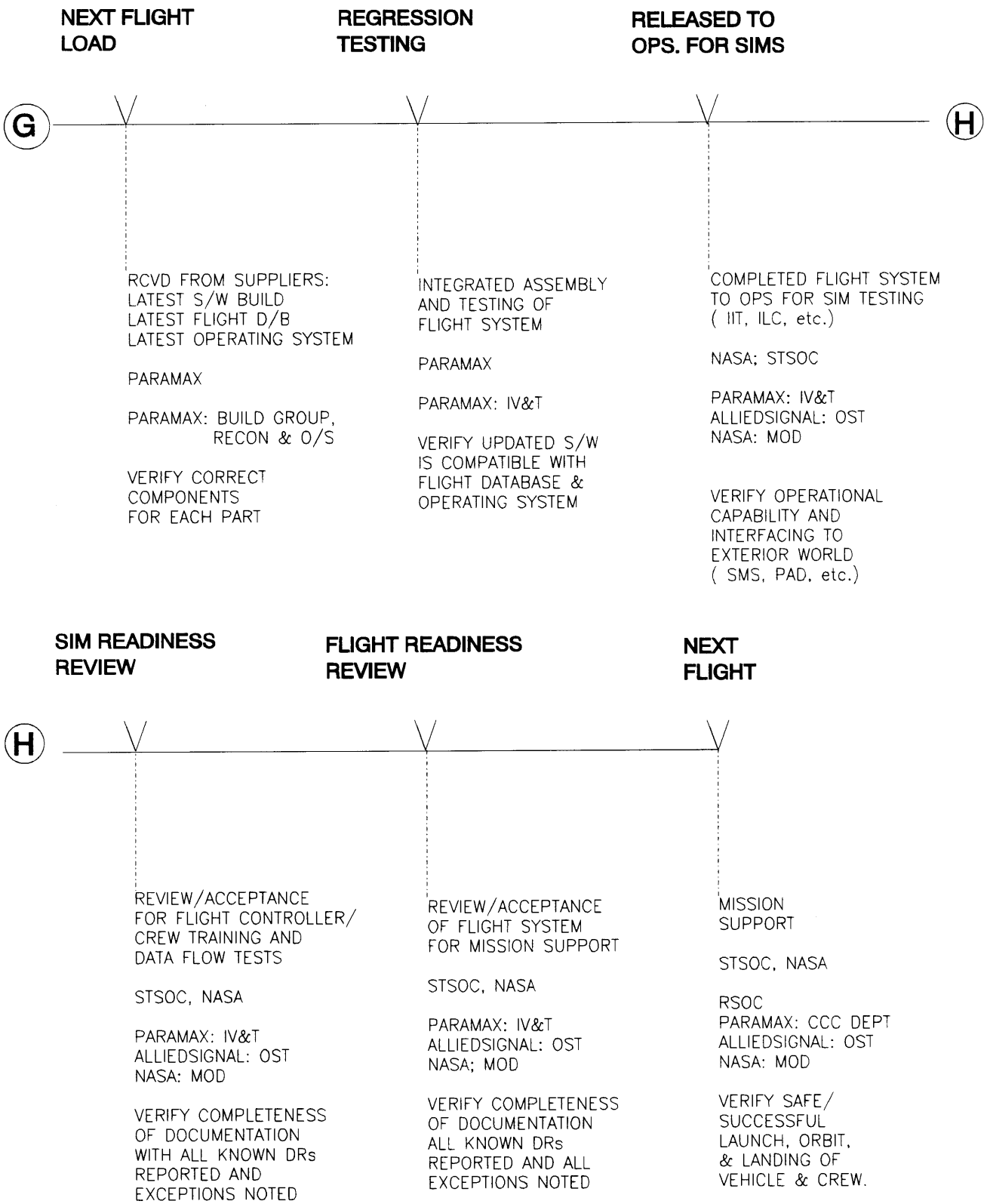


FIGURE E–1

SOFTWARE CHANGE LIFELINE

(Page 7 of 7)



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APPENDIX F

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APPENDIX G

GLOSSARY OF TERMS

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APPENDIX G

GLOSSARY OF TERMS

APL	Application Program Library
ATSC	AlliedSignal Technical Services Corporation
BFS	Backup Flight System
BOC	Base Operations Contractor
CCB	Change Control Board
CCBD	Configuration Change Board Directive
CCC	Consolidated Control Center
CCF	Converter Compressor Facility
CCMS	Checkout, Control and Monitor System
CCN	Code Change Notice
CCS	Complex Control Set
CDR	Critical Design Review
CI	Configuration Inspection
CITE	Cargo Integration Test Equipment
CLCR	Controller Logic Change Request
CM	Configuration Management
CPU	Central Processing Unit
CR	Change Request
CSL	Canoga Software Laboratory
CTR	Certification Test Report
CTS	Charge Tracking System
D&SE	Development and Sustaining Engineering (contractor)
DBC	Data Base Compare
DCN	Design Change Notice
DCR	Data Change Requests
DDS	Detailed Design Specification
DPS	Data Processing System
DR	Discrepancy Report
DVIS	Digital Voice Intercommunications System
ECP	Engineering Change Proposal
ED	Engineering Directorate
EIC	Executable Image Compare
EPDC	Electrical Power Distribution and Control

ESR	Engineering Service Request
ET	External Tank
FACI	First Article Configuration Inspection
FCOD	Flight Crew Operations Directorate
FCP	FSW Change Proposal
FCR	Flight Control Room
FD	Function Designator
FDSD	Flight Data Systems Division
FEC	Field Engineering Change
FEPS	Front End Processing System
FRF	Flight Readiness Firing
FRR	Flight Readiness Review
FSH	Flight Support Host
FSW	Flight Software
GFE	Government Furnished Equipment
GLS	Ground Launch Sequencer
GN&C	Guidance, Navigation, and Control
GOAL	Ground Operations Aerospace Language
GPC	General Purpose Computer
GSE	Ground Support Equipment
GSSW	Ground Systems Software
GSW	Ground Software
HMF	Hypergolic Maintenance Facility
HSL	Hardware Simulation Laboratory
HSL II	Hardware Simulation Laboratory II
HVAC	Heating, Ventilating and Air Conditioning
IBCB	Integrated Baseline Control Board
ICB	Integration Control Board
IDR	Interim Discrepancy Report
IIT	Integrated Interface Test
ILC	Integrated Load Checkout
IMMU	Integrated Mass Memory Unit
IPR	Interim Problem Report
IV&T	Integrated Verification and Test
IV&V	Independent Verification and Validation
JSC	Johnson Space Center
KATS	KSC Avionics Test Set
KCR	KSC Change Request
KSC	Kennedy Space Center

LAN	Local Area Network
LCC	Launch Commit Criteria Launch Control Center Launch Control Complex
LCN	Logic Change Notices
LPS	Launch Processing System
LSOC	Lockheed Space Operations Company
LSS	Launch Support Services
MARS	Mission Automatic Reconfiguration System
MAST	Measurement and Stimulus
MCC	Mission Control Center
MED	Manual Entry Device
MIDDS	Meteorological Interactive Data Display System
MMU	Mass Memory Unit
MOC	Mission Operations Computer
MOD	Mission Operations Directorate
MOST	Mission Operations Space Team
MPSR	Multipurpose Support Room
MSFC	Marshall Space Flight Center
NRT	Near Realtime Telemetry
OAD	Operational/Adaptation Data
OI	Operational Increment
OMI	Operations and Maintenance Instruction
OMRS	Operations and Maintenance Requirements Specification
OMRSD	Operations and Maintenance Requirements Specification Document
OMS/RCS	Orbital Maneuvering Subsystem/Reaction Control Subsystem
OPF	Orbiter Processing Facility
OPS	Operations
PASD	Payload Application Software Definition
PASS	Primary Avionics Software System
PBI	Push–Button Indicator
PBT	Post–Build Test
PDR	Preliminary Design Review
PGOC	Payload Ground Operations Contractor
PR	Problem Report
PRACA	Problem Reporting and Corrective Action
PRCB	Program Requirements Control Board
PTP	Performance Test Plan
PTR	Performance Test Reviews

QA	Quality Assurance
RCN	Requirements Change Notice
RFIT	Ready for Integrated Testing
RMD	Reconfiguration Management Division
RPS	Record and Playback System
RSOC	Rockwell Space Operations Company
RTH	Realtime Host
SAIL	Shuttle Avionics Integration Laboratory
SAN	Software Authorization Notice
SASCB	Shuttle Avionics Software Control Board
SASR	Shuttle Avionics Systems Review
SCCB	Software Change Control Board
SCR	Software Change Request
SDC	Shuttle Data Center
SDF	Software Development Facility
SDPC	Shuttle Data Processing Complex
SES	Shuttle Engineering Simulator
SIO	Systems Integration Office
SIT	Systems Integration Test
SMS	Shuttle Mission Simulator
SN	System Note
SOC	Space Operations Contract
SPC	Shuttle Processing Contractor
SPF	Software Production Facility
SPR	Software Program Report
SQA	Software Quality Assurance
SR	Support Requirement
SR&QA	Safety, Reliability & Quality Assurance
SRB	Solid Rocket Booster
SRD	Software Release Document Software Requirements Document
SRF	Software Reconfiguration Facility (JSC)
SRG	Software Review Group
SRR	Software Readiness Review Simulation Readiness Review
SSC	Stennis Space Center
SSCR	Shuttle Software Change Request
SSE	Software Sustaining Engineering
SSME	Space Shuttle Main Engine
SSMEC	Space Shuttle Main Engine Controller
SSP	Space Shuttle Program

SSPO	Space Shuttle Program Office
SSV	Space Shuttle Vehicle
STAR	Shuttle Transportation Automated Reconfiguration
STS	Space Transportation System
TCID	Test Configuration Identifier
TCS	Test Control Supervisor
TCT	Test Coordination Team
TCTI	Time Compliance Technical Instruction
TDCC	Technical Directive Change Control
TDL	Technical Direction Letter
TPC	Telemetry Preprocessor Computer
TPS	Test Preparation Sheet
TRP	Technical Review Panel
UCR	Unsatisfactory Condition Report
VAB	Vehicle Assembly Building
VCP	Verification Complete Package
VCS	Vehicle Cargo System
VDD	Version Description Document
VTO	Verification Test Outline
VTP	Verification Test Procedures
V&V	Verification and Validation
W/S	Workstation

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